The SCIENTIFIC MONTHLY

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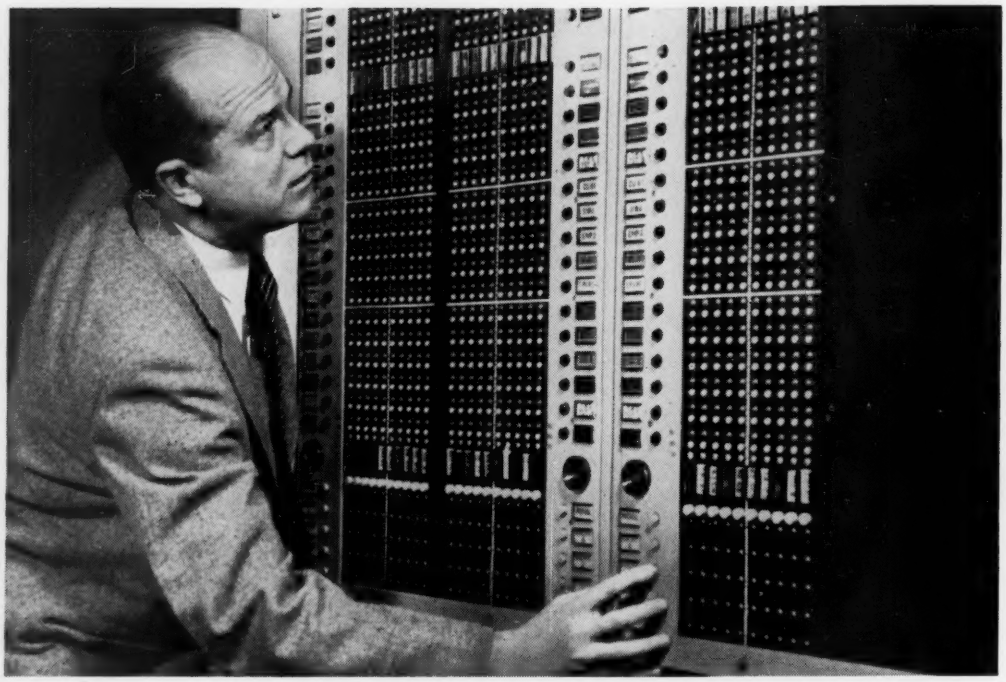

Bell Laboratories engineer Cyril A. Collins, B.S. in EE., University of Washington, demonstrates new TV switching control panel for black and white or color. Complex switching connections are set up in advance; in a split second a master button speeds dozens of programs to their destinations all over the nation. Special constant-impedance technique permits interconnection of any number of broadband circuits without picture impairment.

Telephone science speeds TV enjoyment

Telephone science plays a crucial part in your TV entertainment. An interesting example—one of many—is the latest TV switching center developed at Bell Laboratories.

Switching centers control the transmission of programs which come to your local TV station over Bell System facilities. To be available exactly on cue, programs must be switched at high speed and with very great accuracy.

To create the new switching center Bell Laboratories engineers borrowed from the switching control art which handles your dial telephone calls. They developed a special control panel which puts complex switching patterns within the easy grasp of one man. By pushing buttons, he sets up—and double-checks—forthcoming network changes far ahead of time. On cue he presses a master button which sends the programs racing to their respective destinations around the nation.

To connect the broadband circuits, the Laboratories engineers developed a new video switch which operates on a constant-impedance principle. The new switch permits the interconnection of any number of circuits, without the slightest impairment of transmission quality.

Thus the technology which serves your telephone also works for your TV enjoyment.

BELL TELEPHONE LABORATORIES

World center of communications research and development

THE SCIENTIFIC MONTHLY

VOL. 84 — MAY 1957 — NO. 5

Cover: Rare Orchid

[*Courtesy Jose C. Mendiola and Biological Photographic Association, see page 236*]

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Science and Technology

All inquiries concerning items listed here should be addressed to The Scientific Monthly, *Room 740, 11 W. 42 St., New York 36, N.Y. Include the name(s) of the manufacturer(s) and the department number(s).*

Color Difference Meter

A new color difference meter compares colors in terms of a three-part number, each part of which is obtained by automatic consideration of one of the factors whiteness versus blackness, redness versus greenness, and yellowness versus blueness. The three parts of the number are produced by three null-balance circuits, each of which compares the light reflected from the sample with that reflected from a standard. (Gardner Laboratory, Inc., Dept. M149).

Pulse Generator

Nuclear instruments such as linear amplifiers and radiation spectrometers may be checked and calibrated with a new portable pulse generator. The instrument has a drift rate of less than 0.005 percent per hour. The output is variable from 1 μv to 10 v; the rise time of the pulse is 7 mμsec; the pulse decays exponentially in 300 μsec; and the repetition rate is fixed at 60 pulses per second. (Franklin Electronics, Inc., Dept. M150).

Test Chamber

Ambient testing of products at temperatures from −65° to 600°F can be carried out in a new thermal test chamber. The unit has 600 in.^{3} of working space. Temperature fluctuations are limited to 4°F. Dry Ice is used for cooling, and two 750-watt finned-strip heaters are used for heating. The test trays are interchangeable, and they have ⅜-in. openings for electric or mechanical connections. (Statham Development Corp., Dept. M156).

Auroral Patrol Spectrograph

Designed especially for the International Geophysical Year, an auroral patrol spectrograph produces a horizon-to-horizon photographic record of the spectra of auroras along a meridional line. The camera can be adjusted to photograph spectra from the visible to the near infrared. Exposure is determined by a photometer. Exposure of a standard tungsten lamp provides an index to film characteristics. The instrument is designed to operate in extremes of temperature from −40° to +125°F. (Perkin-Elmer Corp., Dept. M166).

Analyzer

Neutron time-of-flight analyzer has 1024 channels adjustable in width from a minimum value of 0.5 μsec to essentially any higher value. The instrument records 65,535 counts per channel with a dead time of 16 μsec/count. The instrument's memory can be divided into two parts for recording simultaneous but separate events detected by two separate 512-channel analyzers. Possible readouts include a recording potentiometer and a decimal printer. (Radiation Counter Laboratories, Inc., Dept. M243).

Stereo Microscope

Kellner eyepieces (8×) and two sets of objectives on a revolving turret are used on a stereo microscope to provide magnifications of 21 and 34. Working distance is up to 3 in. (Edmund Scientific Co., Dept. M181).

Frequency Meter

Designed to operate in the range from 0 to 42 Mcy/sec, a new frequency meter has an accuracy of ±1 cy/sec. It can also be used as an elapsed-time meter (range, 1 μsec to 10 Msec), an events-per-unit-time meter, a time-interval meter, a period meter, a frequency-ratio meter, and as a high-speed electronic counter. By use of auxiliary plug-in equipment, the range can be extended to 515 Mcy/sec at the same accuracy. (Beckman Instruments, Inc., Dept. M136).

Demonstration Table

Laboratory demonstration table is self-contained and is mounted on rollers. The unit has provision for its own water supply and has an extension-cord outlet to supply electric current. It also has provision for storage of gas cylinders, vacuum or air pumps, and batteries for electric measurements. (Kewaunee Manufacturing Co., Dept. M237).

Nuclear-Powered Battery

Beta emission is converted to light and the light to electricity in a new battery. The light source consists of a mixture of finely divided phosphor and an oxide of promethium-147. Beta particles excite the phosphor to emit red and infrared radiation. Silicon photocells convert the light into electric current. The prototype battery uses about 4.5 of the isotope, which has a half-life of 2.6 years. Nominal power output of a new unit is 20 μw. The battery, which is shielded to eliminate bremsstrahlung, measures 0.2 in. thick and 0.6 in. in diameter. (Walter Kidde Nuclear Laboratories, Inc., Dept. M221).

Spectrometer

Electron paramagnetic resonance spectrometer is capable of inducing and observing electron paramagnetic resonance in substances possessing a resultant electronic magnetic moment. In the case of an unpaired electron, a strong magnetic field will apply a torque to the axis of the resultant magnetic moment. The resulting rate of gyroscopic precession is characteristic of the particular atom and its environment. A variety of conditions influencing the resultant electron magnetic moment can be studied—for example, free radicals, sites of radiation damage, and impurities in semiconductors. The spectrometer operates at X-band frequency (nominally 9.5 kMcy/sec). (Varian Associates, Dept. M206).

Recording Ellipsometer

Monomolecular layers may be studied with an ellipsometer that is designed to permit the measurement and recording of changes of thickness of very thin transparent films deposited on a flat metal mirror. The operation of the instrument is based on the functional relationship between the ellipticity of reflected polarized light and the thickness of the film. Sensitivity is bettter than 0.5 A in the most sensitive thickness range. For materials of refractive index near 1.5, this range is at a thickness of approximately 1000 A. To bring observations into this range, the metal reflecting surface is first coated with a suitable background material. (O. C. Rudolph & Sons, Dept. M175).

Vacuum Furnace

By interchanging furnace components, one can use a new vacuum furnace for melting, annealing, brazing, sintering, and degassing. Model F-1212 accommodates a 3- by 6-in. zirconia crucible and provides temperatures up to 2000°C. The vacuum system includes a 4 in., 320 lit/sec diffusion pump with a liquid-nitrogen cold trap. A combination thermocouple-ionization gage measures the vacuum. (High Vacuum Equipment Corp., Dept. M184).

Magnetic Alloy

"Supermendur," a new magnetic alloy, is said to have higher permeability and lower hysteresis losses at higher flux densities than any material heretofore available. The improved properties are achieved by careful control of composition and treatment. Maximum permeability is 66,000 at 20,000 gauss; remanence, 21,500 gauss; coercive force, 0.26 oersted; and saturation, 24,000 gauss. Core losses are less than 6 watt/lb at 400 cy/sec at a flux density of 100,000 lines/in^2. The hysteresis loop is rectangular with a flux swing of 45,500 gauss from minus remanence to plus saturation. (Bell Telephone Laboratories, Dept. M248).

Atomic Educator

A kit called the "atomic educator" is an assembly of basic equipment necessary for a comprehensive laboratory in the applications of atomic science. The kit includes an electronic scale of 100 and electrochemical six-digit register, high-energy and low-energy Geiger counters, power supply suitable for both Geiger and scintillation counters, and accessories suitable for a variety of quantitative as well as qualitative experiments. (Nuclear Corporation of America, Dept. M218).

Television Camera

The size of a camera designed for closed circuit television has been reduced to 1⅞ by 2⅜ by 4½ in. When it is used with an F1.9 lens, the camera requires 10 ft-ca of scene illumination for clear-contrast pictures. Photoelectric iris control provides accommodation to variation of lighting of 100 to 1. The camera requires 350 watts of 115-v, 60-cy/sec power. (Radio Corporation of America, Dept. M212).

Glass

This Is Glass is the title of a 64-page booklet devoted to the manufacture, applications, and history of glass. (Corning Glass Works, Dept. M198).

Radioactive Chromatograph Scanner

Automatic graphical presentation of the distribution of radioactivity along a paper chromatogram that is tagged with low-energy beta-emitting isotopes is provided by a radioactive chromatograph scanner. The instrument employs a small, low-background flow counter that can be operated without a window. Chromatograms up to 3 in. wide and 5 ft long can be accommodated. The scanning head is removable, and windows, when used, are easily replaceable. Rectilinear recording at 10 different scanning speeds is provided. Scanning is automatically interrupted when the end of the chromatogram is reached, and a signal alerts the operator. (Forro Scientific Co., Dept. M163).

Displacement Follower

Displacement follower does not require contact with the object that is to be followed. An intense spot of light from a cathode-ray tube is focused onto the edge of the moving object. Reflected light from the illuminated spot is picked up by a photocell and used to keep the cathode-ray beam positioned on the edge of the object. Thus the spot of light on the cathode-ray-tube screen traces the motion of the object. A number of models of the instrument are available, with full-scale ranges from 0.1 in. to 4 in., resolutions of 1 part per thousand, and signal output of 40 v full scale. Band width is 0 to 5000 cy/sec. Output impedance is approximately 1000 ohms. Working distances range from ½ to 9 in. (Optron Corp., Dept. M240).

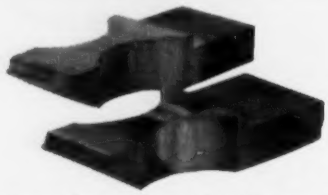
Microwave Generators

Interchangeability tuning units permit microwave generators and sources to cover the frequency range from 18,000 to 50,000 Mcy/sec. The tuning units require no further adjustment after plug-in to the basic unit. The self-contained instruments provide continuous-wave or modulated signals of known frequency. (Polarad Electronics Corp., Dept. M200).

Ultraviolet Analyzer

Designed for continuous monitoring and control of petroleum and allied processes, a new ultraviolet analyzer is of the nondispersive type; filters sensitize the instrument to the component of interest. Radiation wavelengths from 200 to 280 mμ are used. A hydrogen-discharge lamp is the source of illumination. The chopper- and sample-modulated beam is detected by a multiplier phototube. An automatic zero-drift standardization system compensates periodically for long-time drift caused by such factors as fogged windows and lenses, variations in ambient temperature, and aging of the light source. The sample must be clean, dry gas with a flow rate of approximately 1000 cm^3/min. (Consolidated Electrodynamics Corp., Dept. M232).

New Kentanium pinch-off jaws.



Kentanium jaws after pinching and sealing over 215,000 tubes. Note the small amount of wear on this set.

KENTANIUM* jaws pinch off and seal HOT glass tubing at 1500°F to 1700°F

Jawlife increased ten-fold

To provide a tight seal for vacuum purposes, glass tubing is pinched off and sealed with pinch jaws made of Kentanium, a heat-resistant titanium alloy that retains great strength and resists abrasion at high temperatures.

Formerly, pinch jaws of alloy steel or chrome carbide were used. To prevent the hot glass in a semi-plastic state (1500°F to 1700°F) from sticking to the jaws, powdered graphite was used as a lubricant. After the pinch-off, an extra glazing operation was necessary to *completely seal* the tubes to retain vacuum. Life of jaws: only 20,000 to 25,000 tubes.

As the non-galling characteristic of Kentanium is effective in glass forming operations (when in semi-plastic state), it was applied and the need for a lubricant during the pinch-off operation was eliminated. The extra glazing operation also was eliminated because Kentanium produced a clean, tightly-sealed pinch-off. Results: life of Kentanium jaws average 215,000 tubes.

This is just another example of how Kennametal* compositions help engineers to solve problems requiring metals which have high resistance to heat, abrasion, corrosion, deflection, deformation, galling or impact. Perhaps you have such a problem. Then we invite you to write KENNAMETAL INC., Dept. MS, Latrobe, Pennsylvania. One of the many Kentanium or Kennametal compositions may provide the answer.

*Trademarks of a series of hard carbide alloys of tungsten, tungsten-titanium, and tantalum.

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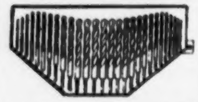

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Dept. 7105, 611 Broadway, New York 12, N. Y.

THE
SCIENTIFIC MONTHLY

MAY 1957

Changing Energy Scene

CHARLES A. SCARLOTT

Mr. Scarlott is manager of the publications department, Stanford Research Institute, Menlo Park, California. After his graduation in 1925 from the University of Arizona, with a B.S. degree in electrical engineering, he joined the Westinghouse Electric Corporation in Pittsburgh where, until 1954, he edited the company's technical publications. He has written and spoken extensively on engineering subjects, particularly in the field of fossil fuel energy and solar energy. This article is based on a paper presented at the Energy Resources Conference in Denver, Colorado, 29 October 1956.

RECENTLY a San Francisco newspaper headline proclaimed the possibility of gas rationing as a result of the Suez Canal crisis. Tucked away in the same paper was a story about one organized group advocating restrictions on oil imports in order to diminish our oil surplus.

For a subject that is supposed to be susceptible to discussion in terms of numbers, that of energy sources is a complex of contradictions. We hear of reserves of coal—the major fossil fuel—mentioned by some in terms of 1000 or more years; by others, as no more than a century. Some predict serious crude-oil shortage in a dozen years, others pooh-pooh the idea.

No wonder the layman is confused! The number of words spoken and printed about energy would make a sizable mountain. However, all known, or nearly known, honest-to-goodness data about fuels, reserves, historical rates of use, and so forth, can be contained on a single sheet of paper. All else is opinion, masquerading under the guise of interpretation.

Sometimes it seems that most students of energy resources seek the largest possible number of opinions, hoping to take a composite of them and thereby arrive at more reliable figures. It is a feeling that there is safety in numbers. The soundness of this is questionable. Many speakers and writers on energy—and I am not excluding myself—are simply taking the few known numbers and the many guesses and rephrasing them in their own words. Too often nothing is added in the process.

Before we can dwell on the overtones and highlights of the energy picture, we must first sketch in the basic outlines. Let us look quickly at each of the major fuels in turn. I shall start with what seems to me the simplest: oil.

The basic facts about oil are these. The figure given for proved reserves, in the United States, of crude oil and natural-gas liquids is about 35 billion (10^9) barrels. Present annual consumption is about 3 billion barrels, of which nearly 15 percent is imported. How much more than the 35 billion barrels will ultimately be discovered and recovered is obviously unknown. The figure differs with the degree of optimism or pessimism of the guesser. Most of the "guesstimates" fall between 75 and 100 billion barrels yet to be produced. The largest area of doubt is in the recovery of oil from offshore wells.

On a straight numerical basis, and with consumption rising, these numbers say that we have oil for another 20 to 25 years. However, this is a completely useless bit of mathematical exercise. In the first place, we cannot—if we wanted to—pump oil from the wells at a continuing high rate until

they are dry. Furthermore, the dividing number (rate of consumption) is steadily and steeply rising. Actually wells in this country will be producing oil a century from now but probably at a trickle rate.

What is really important about any fuel is not how much, in absolute numbers, but how much with respect to demand. Here the oil situation is clearer—and grimmer.

Production in the United States does not now meet demand and has not since 1947. We have enough production capacity to cut the amount of oil imports perhaps in half, if need be. By feverish operation of the wells, production could be made almost equal to consumption, for a short period, but it would be wasteful in the long run.

The oil deficit is not a serious one at present, even with imports from the Middle East temporarily cut off. The difference between United States production and consumption has been, and for a time will be, made up, without economic handicap, by imports. But, for how long? This is the question.

It is commonly assumed that the deficit can be overcome by increasing imports. I doubt that such a blithe assumption is justified. It fails to take into account the rapid rise in demand for liquid fuel in the other nations of the world.

The world beyond our borders is rapidly catching up with the United States in oil requirements. Oil, as we well know, is habit-forming. Demand for oil in the rest of the world has been growing about 4 times faster than it has here. Of course, the demand here far exceeds that of every other country. In 1953, per capita consumption in the United States stood at 17.5 barrels, whereas per capita consumption in Western Europe, for example, was 2.3 barrels, and in the world as a whole—minus the United States—about 1 barrel. Thus, in 1953 we were using oil at the rate of 17.5 times that of the rest of the world, but in 1930 we were using 28 times as much.

The only guide for an estimate of future demand outside the United States is the trend of the past several years. A good round number for our purpose is 10 percent per year. However, the present annual consumption of the rest of the world, compounded annually by 10 percent to 1975, would reach the impossible total of 49 million barrels a day, or about 18 billion barrels a year. This is nearly 3 times the probable world production in 1975!

The only conclusions that can be reached are that the peoples of the rest of the world will want far more petroleum than they can possibly get; consumption will have to be tailored to supply; deficits will have to be made up by synthetics; and the United States will not long be able to make up its deficiencies of petroleum without starving the other nations—an expedient that is politically impracticable. It also means that the world price of oil will no longer be fixed by cost but will be determined largely by demand.

If these conclusions are approximately correct, and if we are either unable to make up the differences between United States oil production and demand by buying in the world market or are unwilling to pay the price in the seller's market, it seems inevitable that we must turn for additional liquid fuel either to oil shale or to coal, or to both. To go without liquid fuel is unthinkable.

Another key date, when considering oil, is the year of peak of production—a date over which we have little control. After that time, crude-oil production will begin its long, inexorable decline. After this point has been reached, the gap between production and need will widen at a shocking rate.

What is that date? Again the experts differ. More of them say that it will be within 10 years than later. This is a sobering thought.

One is tempted to ask how such unpleasant predictions can be reconciled with the recurring news of large oil discoveries, such as the comparatively recent finds in the Williston Basin of North Dakota or those of western Canada. The answer is that, while such discoveries are important, the news of them usually does not present them in proper perspective from the standpoint of size. The present proved reserves of the Williston Basin would supply the United States at its present rate of use for less than 1 month. The proved reserves of Canada are presently given as 3 billion barrels—1 year's consumption in the United States. Undoubtedly more than that quantity will be recovered, because the fields of western Canada are young, and additional discoveries will be made. The largest figure I have seen for Canadian reserves is 30 billion barrels by 1980. This is equal to 10 years' supply at our present rate of use. It should be pointed out, too, that in Canada oil consumption is still twice the oil production. Oil production and consumption are both rising in Canada.

To keep even with consumption, the oil companies in the United States must make eight 1-million-barrel finds every day. To do this is becoming increasingly difficult—and expensive.

Natural Gas—a Better Picture

With regard to natural gas, the picture is a bit rosier. In round numbers, proved reserves are about 210 trillion cubic feet and are not changing much from year to year. Most students of the subject expect total future recovery to be in the neighbor-

hood of 600 trillion cubic feet—or 60 years' supply at present rate of use. Again, this is a meaningless figure. We must remember that use of natural gas is rising faster than use of any other fuel. Consumption of gas has doubled, on the average, every decade since 1900. I believe a fair estimate is that the peak of gas production will occur about 1980, with demand exceeding ability to produce by a serious amount within the following 10 years.

Coal—a Complex Story

The subject of coal is too large and too complex for me to do more than set forth the salient facts, with little elaboration.

1) In grand total the United States possesses a prodigious amount of coal.

2) However, every time a new estimate is made of recoverable coal the tonnage becomes smaller. The figure generally quoted as total coal reserves, up to a dozen years ago, was about 3 trillion tons. Now preliminary figures of a reinventory by the U.S. Geological Survey give a little under 1 trillion as eventually recoverable, with the prediction that the final totals will be less than that.

It appears that we have roughly 50 billion tons (less than 100 times present production) that can be produced within the present economic framework, an additional 200 billion tons that can be produced at higher cost, and perhaps 350 billion tons that we are not sure about. These figures bear no resemblance to figures that were commonly accepted as recently as one decade ago. In assuming that we had enough coal to supply us with energy for "thousands of years," we were living in a fool's paradise.

3) Unlike oil and gas, coal is of many grades or ranks. Unfortunately, the better qualities—the low- and medium-volatile bituminous—are but a few percent of the total, and they are the ones which now constitute the greater part of total production. It is these bituminous coals, furthermore, on which the steel industry relies for metallurgical coke.

About 55 percent of the 50 billion tons of "most-available" coal is bituminous, and most of the remainder is subbituminous and lignite. But the low-volatile bituminous that is so important in the manufacture of coke for blast furnaces amounts to only a few hundred million tons. We are close to exhaustion of easily procurable, high-quality coking coal.

4) The principal factor that makes the coal picture so uncertain is not whether the coal is present but what we can consider recoverable by economic means. As with all resources, we are taking the best coal and the coal easiest to get first. Mines are having to go deeper; seams are getting much thinner. Both will affect costs and will eventually pinch off production, even though lots of coal remains where it was laid down.

5) The amounts of subbituminous and lignite are enormous. The deposits lie mainly in the western states. Fortunately, these coals are quite acceptable for conversion to oil, gas, and chemicals, and for steaming fuel.

6) The steady decline in coal production since 1947 has, in all probability, ended. From a low point of production in 1954 (394 million tons) it had risen to about 500 million tons last year.

The situation is neatly summed up by Eugene Ayres (*1*), whose professional career has been spent not in coal but in the oil business: ". . . all signs now seem to point toward an almost explosive expansion in the U.S. consumption of coal. . . . By 1958 I believe that demand should be about 600 million tons; 1960, 640 million; 1965, 900 million; 1970, 1200 million. Reasons for such rapid rise are (i) rate at which electric power demands are increasing; (ii) inadequate potential capacity of hydro power; (iii) expected peaks of production of natural petroleum and natural gas around 1965 and 1975, respectively; (iv) expected peak of production of world petroleum between 1985 and 2000; (v) expected high rates of domestic and world demands for liquid fuel."

So much for the triumvirate of fuels—oil, gas, and coal. There stands on the sidelines, so to speak, waiting a call to take its place in the energy game, shale oil.

Oil Shale

In essence, the facts regarding shale-oil recovery as I see them are the following.

1) We have oil shale in great quantity. In spite of the figures given, we actually have no more than a sketchy idea of just how much. But it is a lot.

2) Oil of acceptable, but not superlative, quality can be obtained from shale by well-proved processes to the extent of between about 25 and 40 gallons per ton and at costs not much above those of crude oil.

3) With shale-oil technology steadily improving, and with crude-oil costs inevitably rising, commercial production of oil from shale seems inevitable, and that day is probably not far distant. However, it is difficult to visualize the time when oil from shale is sufficient to meet more than a small fraction of the demand for liquid fuel.

It is to be hoped that developments to recover oil from shale *in situ* will be successful. We may possibly see the heat from another energy source native to the oil-shale region—uranium—used to

drive the recovery process. These efforts to recover oil without shale mining would no doubt pose new problems, but they would solve the extremely serious ash-disposal question. Also they would enormously increase the shale-oil reserves, since recovery would be possible from much greater and, in some cases, richer depths than by mining.

Tar Sands

I simply cannot get exercised about tar sands, for the following reasons.

1) They exist on this continent in small amounts, relative to the demand for oil. Oil, if it could be recovered from the sands known to exist in Canada, would be equivalent to only a year or two of United States oil consumption.

2) What there is, is mostly in Canada. The United States has comparatively little tar sands.

3) The problems of extracting bitumen from tar sands are great. The application of the word *sands* to this resource is an abuse of the English language and very misleading.

4) No one has come within range of a practical, economical process for inducing tar sands to give up their hydrocarbon content. Perhaps someone will some day, but let us not count on it.

Fossil Fuels in Total

Actually, I place little store in efforts to determine the life of our fuel supplies. One comes inevitably to the conclusion that, measured against rising use, the period of adequacy is distressingly short, no matter how optimistic one chooses to be regarding reserves.

Try a bit of arithmetic. Take any number you wish, to represent years of supply of total fossil fuels in our earth bank at present rate of use. For example, take 1000 years as a nice, large, round number and the 1950 rate of use as a convenient base.

By 1975 it is expected that, with our explosive rate of population growth and with the ever bigger per capita appetite for energy, use will be at least double that of 1950. Hence our 1000-year supply will have become something like 470 years' worth at the 1975 rate of use.

Rate of use by the end of the century will be at least 4 and more likely 5 times 1950 consumption. The remaining fossil fuels would last, at the year-2000 rate, about 200 years.

Estimates for rate of use by 2050 vary, understandably, over a wide range. I have not seen any guess of less than 10 times the 1950 rate, and I have seen guesses as high as 135. Let us take a low number within this span—say 20, or an average of 10 times the 1950 rate over the first half of the 21st century.

How much fossil fuel do we have left in 2050, according to the assumptions we have been following? The answer is *None*.

This bit of logic is perhaps absurd but rather graphically illustrates the general situation. In 2050 men will almost certainly still be mining fossil fuels but at a rate woefully inadequate to the needs. It is almost certain that children of men now living will see the day when fossil fuels are virtually exhausted.

Water Power—a Minor Source

Just to keep the record straight, let us mention the contribution of water power to our energy needs. At the turn of the century, energy from water power amounted to about 4 percent of total use and today, despite increased development, it still amounts to no more than approximately 4 percent. Because the best water-power sites have already been developed, we can expect that it will begin to fall behind in terms of percentage. Water power is foredoomed to play a useful but minor role in the energy drama.

Nuclear Energy—the Great Unknown

Any attempt to make hard and fast predictions about nuclear power at this stage is almost wasted effort. This is forcibly illustrated by the experience of one group who tried some nuclear-power forecasting. Early in 1955 the Atomic Industrial Forum, a substantial organization in the field, made an estimate of the amount of private capital that would go into nuclear-power development in the United States in the next 5 years. Just 9 months later, more than that amount had been committed. Its 5-year estimate was 4 years and 3 months off. I shall, accordingly, confine my comments on nuclear-power developments to several general statements.

1) The early belief that we—particularly in the United States—have only scant amounts of recoverable uranium has been dispelled. The reserves of uranium ore are large but finite. Only recently has the Atomic Energy Commission given much clue to their size. The released figures (*2*) give, without specifying the uranium content, the present known total of uranium ore deposits considered workable as 60 million tons, of which 40 million are in New Mexico, 7.5 million are in Utah, and 4.1 million are in Colorado. Without question, reserves of uranium and thorium in this country and

abroad are sufficient to support a major electric-power development program for many decades to come.

2) What the true cost of nuclear-produced kilowatts will be is simply not known now and will not be for some time. Furthermore, experience figures cannot be known for quite a while. No major nuclear-power station will go into service in this country within a year. Even the first ones will not tell much cost-wise, because they were not selected as the most economical types. Also, the prices for fuel are still completely artificial. This may change soon, for it is expected that some countries may place uranium on the open market. Likewise, the cost of spent-fuel processing is not known. The only plants in this country equipped to process fuel elements are the AEC plants at Oak Ridge, Hanford, and Savannah River, and these are not at all representative of what privately operated processing plants would be.

3) In spite of this, it can almost be taken as a certainty that large nuclear-energy power stations will, sooner or later, be competitive in delivered kilowatt-hour cost with fuel-fired plants. I do not think it will be very long.

4) Nuclear-fuel stations will begin, in 3 to 5 years, to comprise a rapidly increasing percentage of new large electric generating stations. The installation of nuclear-power stations in other well-developed nations of the world will probably proceed, percentage-wise, at an even faster rate than in this country because of their lack of fuel or the high cost of conventional fuels.

The present outlook is for about 1 million kilowatts of installed nuclear-power capacity in the United States by 1962—assuming that the insurance problem can be resolved. The U.S.S.R., which takes insurance problems more lightly, will probably have 2 million kilowatts operating by 1960. England, hard pressed for energy, will also have about 2 million on the line in 1960. The world oil crisis will possibly spur this program faster. However, these figures are no discredit to nuclear-power skills in this country. The objectives, the needs, differ. Those who urge this country into a nuclear-power race simply to be first are doing the country a disservice.

5) Electric-power production consumes only about one-fifth of the total energy input in the United States. Hence, even if all electric power were produced by fissioning atoms, the drain on fossil fuels would be relieved only by a fraction.

6) It is probable that, for the next 25 years, United States energy demand will rise faster than nuclear-power stations will go into service. This is in spite of the fact that, by 1975, probably three-fourths of the new, large power stations built will be nuclear.

Fission Batteries

It has been suggested that an important secondary source of nuclear power may be storage-battery power plants based on the heat release from radioactive fission products created in a nuclear reactor. Something like 10 percent of the energy of fission resides in the radioactive by-products of heavy-nucleus splitting. This energy appears eventually as heat, as these isotopes, in their own good time, change into stable forms, liberating heat in the process. The half-life rate at which this is accomplished may be seconds or decades of years, depending on the particular isotopes involved.

Probably fission-type heat sources will be useful and may even become common for certain special purposes, particularly where portability and energy storage are important. However, we can hardly look to this source for any major amount of power. The amount of energy in reactor-generated isotopes with half-lives in the range of practical interest is too small for any big-time operation. If all electric power produced at present in the United States came from fission reactors, the fission products could produce only about 400,000 kilowatts of heat at 100-percent efficiency, or 80,000 kilowatts at 20-percent over-all efficiency.

Reactors for Space Heating

If fission-type power plants eventually took over the whole job of electric-power production, the energy problem would still be only one-fifth solved. Roughly, four-fifths of our energy output goes for expenditures in which electricity plays no part. These are, primarily, transportation, industrial processes, and space heating. This last—comfort heating—itself takes about 30 percent of the British thermal unit grand total.

Direct application of nuclear energy for house heating is an unlikely prospect. However, nuclear reactors are quite likely to become important as industrial or large-scale heat sources, quite aside from electric-power production. For some situations, reactors will be preferred heat sources. For plants requiring large amounts of process heat, or where fuel is scarce or expensive, heat reactors may become more than simply competitive. Norway is considering a heat reactor of 10,000 to 12,000 kilowatts of heat to provide process heat for a large pulp mill. An experimental reactor is being considered in Sweden as a central heating system for the city of Västerås, which has a population of

65,000. Some of the more obvious possible applications of heat reactors are iron refining, ore reduction, shale-oil recovery, and perhaps even water distillation.

Solar Energy

Any discussion of energy sources invariably leads to a consideration of solar energy. It is the one continuous source. Since other sources of energy, including nuclear energy, are finite in amount and are subject to an enormous and increasing drain, the continuity of the sun's rays is unique and compels us, if for no other reason, to give them consideration as a source of energy. It would be comforting if we could spend our fossil fuels at a mad pace, knowing that when they are gone we could handily switch to the sun. Examination of the facts warrants no such complacency. Solar energy is a large subject in itself, but any consideration of its use must be against a background of three facts established by the nature of things, which man is powerless to alter.

1) The total amount of energy received from the sun is enormous. It falls on the earth (and sea) surface at a rate of some 2000 times the amount of energy that man presently contrives to use.

2) While large in total amount, solar energy is diffuse (otherwise we would not exist). A convenient rough measure is 1 kilowatt per square meter during several hours of midday in the middle latitudes. This is all there is. No lenses or mirrors can change it, widespread concepts to the contrary notwithstanding. This figure is important. It rules out as impractical many desirable applications.

Just for example, it is simply impossible to conceive of large-scale, sun-powered electric generating plants. A 100,000-kilowatt power plant is small by today's standards. But a 100,000-kilowatt solar generating station would require a collecting surface of 1 million square meters, assuming 10-percent over-all efficiency. That is 250 acres of active collecting surface—to provide 100,000 kilowatts of electricity during about one-fourth of each cloudless day!

3) Sunshine, obviously, is not only intermittent but variable. This introduces the need for storage.

These facts do not eliminate the possibility that energy captured from sunshine will have a major place in the total energy picture. However, it does mean that solar installations are most likely to be either (i) small in unit size and for local use, as for house heating and cooling, or (ii) for organic or inorganic processes resulting in energy storage, such as plant or animal culture, or water dissociation.

Straws in the Energy Wind

So much for a review of reserves, rates of use, and probable life of known sources. All this has been repeated many times. It seems to me more interesting, and quite as fruitful, to focus attention on items in the news that illustrate trends in energy development and use.

The word *energy* is dynamic and suggests change. Around us every day, in the newspapers and in our particular businesses, we observe the ever-changing hues of the energy picture. In fact, the number of items in the news that have energy connotations is surprising. For those who are energy-minded, it is interesting to interpret these developments in terms of energy, even though energy is not mentioned. Several such items, selected more or less at random, follow.

Road building. The last Congress whittled down President Eisenhower's request for a 10-year, $100-billion federal road-building program to one of about $30 billion to be spent over 13 years. This is on top of the approximately $5.5 billion currently spent each year for roads and bridges. What does this total program mean in terms of energy?

We can assume that for the next 12 to 15 years this country will spend $10 billion per year on roads. To judge from experience, with figures averaged for the country as a whole, we can accordingly expect that the earth-moving and road-building machinery and allied equipment will consume, in that period, the stupendous total of 18 to 22 billion gallons of gasoline, oil, and grease. This is at the rate of 1.5 billion gallons per year, or about 3 percent of the present U.S. annual consumption of motor fuel, which now stands at about 50 billion gallons yearly.

In addition, for every $100 billion worth of constructed road, 1250 million barrels of cement and 30 billion tons of bituminous aggregates must be supplied. To manufacture these 1250 million barrels of cement will require 30 billion kilowatts of electric energy and the equivalent of 9 billion gallons of petroleum for direct-heat energy.

Road building is costly in terms of energy. However, when creeping along at a snail's pace through traffic, who would say that it is not worth it? Yet we have the uncomfortable feeling that this traffic situation is a vicious circle: more roads mean more automobiles and create more traffic, more confusion, and greater demands for more roads. The obvious solution to the traffic problem is not to build more roads but to tear up those that we already have.

Plastics. Another little item tucked away in the back pages of a recent newspaper has an interesting energy implication. This item spoke of the growing use of polyethylene film as a cover for

growing plants. In numerous experimental installations, the transparent film is laid, in sheet form, over vegetable gardens (tomatoes, for example) with holes cut for the plants. The result is a significant reduction in moisture loss, virtual elimination of weeds, and a total increase in crop output of up to 50 percent. The film has even been used experimentally as a covering for irrigation ditches, to prevent evaporation, and as walls for small greenhouses. Only about 1000 acres of polyethylene film have been used for agricultural purposes. However, some believe that in a few years the amount may well rise to 100 million pounds, or 50,000 tons, yearly. Total polyethylene production, for all uses, at present runs to about a quarter of a million tons and calls for about 2.5 million gallons of petroleum products.

Soap. An inconspicuous news story about a year ago told of the fierce, competitive struggle between soap and detergents, with soap definitely on the losing end. In effect, soap is fast becoming a victim of technologic unemployment. Detergents are muscling soap off the grocery shelves. The surplus of tallow and grease, the traditional raw material for soap, at present amounts to more than a billion pounds per year in the United States. Already something more than half of the soap market has been taken over by the synthetic cleaning agents, and the battle is not over.

The significance of this is that technology has shifted the origin of today's principal cleaning agents from the sunshine of summer before last to the sunshine of several million years ago that produced petroleum.

Natural-gas liquefication. Coal and petroleum flow freely through the world's trade routes, by sea as well as over land. This has not been the case with natural gas. It has been assumed that natural-gas markets must lie within pipeline reach of the fields. This may not always be true.

Serious and well-financed experiments are under way to transport natural gas as a liquid in large insulated tanks. If the experiments are successful, gas will be liquefied (at −258°F), transported by water, rail, or other means to points not now served with gas, and reconverted to a gaseous state for local distribution. The cooling effect of the expansion will perhaps be used for local refrigeration purposes.

Within the continental United States, such a development does not seem to have great significance. However, in the total world energy picture, it may be useful; for example, much of the gas now being wasted in the Near East might conceivably be so transported to the energy-short nations of the British Isles and Europe. Such is the ever-changing aspect of the energy picture.

Natural gas as a raw material. A relatively small amount of natural gas is used for other than heating purposes, although the use of natural gas as a raw material for ammonia fertilizer manufacture is increasing. The trend to employ natural gas as a raw material for various products can be expected to increase. At least one major gas supplier is experimenting with separating natural gas into several components by refrigeration and subsequent differential evaporation. This firm predicts that "some day the components of natural gas will be more valuable than the composite itself."

New metals. The men who are dreaming up our supersonic jet planes, intercontinental missiles, and space rockets speak of the requirements for light metals—aluminum, magnesium, titanium, and perhaps even beryllium—in prodigious tonnages. These new metals and their alloys suggest an exciting future for an all-new air age, but they make those of us who are concerned with energy resources shudder. That the production of aluminum requires an enormous sum of British thermal units—about 18,000 kilowatts per ton—is generally understood. Magnesium requires about 22,000 kilowatts per ton. But in the energy-consumption department, titanium makes pikers of aluminum and magnesium. The production of a ton of titanium absorbs about 40,000 kilowatts.

Chemical fuels. The new air age is also responsible for the currently most dramatic news in the energy field. The development of extremely high speed aircraft, and particularly of rockets that must be completely self-contained with respect to fuel, has made it necessary to create whole new categories of fuels. These are alluded to as high-energy fuels or chemical fuels, to distinguish them from conventional petroleum-based liquid fuels.

Although we are only on the threshold of developments in this new field of "superfuels," there are at least 100 new combinations of fuels—oxidizers, and even some high-heat-release combinations in which oxygen plays no part. There are unsymmetrical dimethyl hydrazine, boron nitride, nitrogen tetroxide, pentaborane, nitric acid, liquid oxygen, ozone, hydrogen peroxide, fluorine and lithium compounds, and hydrogen, to mention but a few. Further major developments can be expected at any time. Within 2 or 3 years, the industry required to manufacture these special high-energy fuels will be a billion-dollar-a-year business.

The need for special fuels arises from the requirements of high-speed aircraft for tremendous rate of heat release and for light weight. The quantities of fuel and oxidizers used by missiles and rockets in short times, usually measured in seconds, are tremendous. The V-2 rocket of World War II fame, with its 29-ton thrust, consumed 123 pounds

of fuel and 152 pounds of liquid oxygen per second. Rockets are already in existence with something like 4 times the thrust of the V-2. Hence, the fuel systems of such a missile must handle a half-ton of liquids each second.

From an energy standpoint, the new aircraft fuels mean an additional drain on our fossil-fuel reserves. Many of the fuels and oxidizers do not come directly from coal, oil, or gas. However, in every case, without exception, their manufacture calls for large energy expenditures. And we have seen only the beginning of this trend. Production of a ton of liquid oxygen, for example, requires the investment of 940 kilowatt hours. Present United States production of liquid oxygen is about 2200 tons per day, or an energy investment equivalent to about 375,000 tons of coal per year.

There may be a single possible exception to this air-age drain on fossil-fuel reserves. It is conceivable that the present research efforts to dissociate water, with solar energy and appropriate catalysts, may some day be crowned with success. This will require a major technical breakthrough, inasmuch as the efficiencies on the present test-tube research, to date, are woefully low—well below a fraction of 1 percent. However, in theory, this reaction can be made to work. If so, we may see the day when large areas of present wasteland in sunny areas are large-scale producers of hydrogen from sunshine and water.

This would have tremendous significance. It would solve at least two major energy problems. It would solve the problem of solar-energy storage and would provide the most concentrated chemical fuel that it is possible to obtain. The heat released by burning a pound of molecular hydrogen is 52,000 British thermal units. By comparison, the burning of a pound of carbon releases 14,000 Btu; gasoline, 18,000 Btu; lithium, 18,000 Btu; and boron, 25,000 Btu.

Coal conversion. The eventual production of liquid and gas fuels from coal is inevitable. For the most part, it has been assumed that these processes will be based on, or akin to, the well-developed hydrogenization or gas-synthesis techniques. However, these processes are costly in terms of energy. With either of them, better than half of the energy content of the solid fuel is wasted.

Savings in British thermal units can be effected by processes to produce the luxury forms of fuels by only partial conversion of coal. If the conversion is carried only part way, as by low-temperature carbonization, leaving a solid burnable char (and valuable chemicals), the heat loss is greatly reduced.

Thus, it is possible to visualize the existence, in another 12 to 15 years, of an integrated fuel industry in which conversion plants close to lignite or subbituminous coal deposits produce (i) liquid or gas, or both, for pipeline transmission, and (ii) chemicals and electric power from the remaining char. It is also fairly easy to imagine one further step. Heat for the partial conversion may come from an atomic reactor, particularly in areas where water is short, which is a common situation where low-rank coal deposits are prevalent.

Several plants, of more than pilot dimensions, for partial conversion of coal are already under construction or on the drawing boards. In every case, their present economic justification is not the production of gas or liquid fuels. Instead, high-value chemicals or some other material, such as electric furnace carbons, are the principal products; gas and oil are minor, but immensely significant, by-products.

Controlled Fusion

The one possibility that may completely alter the picture of future energy supplies is controlled fusion. Vast sums are being spent in this country (on Project Sherwood) and in other countries, in the hope of mastering the fusion reaction. Although the difficulties are staggering, the rewards of success would be momentous. For example, if the deuterium-deuterium reaction could be maintained and controlled, it would be possible to obtain, from a single gallon of ordinary water, enough energy to supply the electric requirements of the average American home for a year.

Conclusion

Even a cursory review of the resources and use of energy suggests that no general, world energy famine is imminent. However, the amounts of stored fuels and the rates of their use are such as to show that the world as a whole and many portions in particular are heading rapidly toward serious energy shortages. The problems are not those of competition between fuel forms but of how the most can be obtained from every available source. At best, the development of nuclear power will ease the rate of drain on fossil fuels; it will not eliminate any fuel problem. And as for controlled fusion, it is interesting as a subject for speculation and as a challenge to technical ingenuity, but it can by no means be counted on to spare us the discomfort of the energy shortages that loom ahead.

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Livestock Parasites and Grass

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THE role of internal parasites in the economy of livestock production in this country may be gaged by the estimated losses chargeable to the depredations of these pests. Aside from mortality losses, which are very difficult even to estimate, other losses, much more costly in the long run, result from reduced yield and depreciation of animal products; condemnation of carcasses, or parts, under adequate meat inspection procedure; waste of feed, labor, and space in livestock operations which involve stock debilitated by parasites; reduced quality of animals; interference with breeding and reproduction; inefficient utilization of pastures; and lowered resistance to bacterial, viral, and other diseases in animals that are burdened with these internal marauders. The total losses to our livestock and poultry producers have been estimated by the United States Department of Agriculture as about $430 million per year. This figure has been thought too conservative in some livestock quarters. The figure given in the January 1955 issue of *Livestock Conservation News* to represent the toll which parasites exact from the resources of our livestock and poultry producers is in excess of $900 million per annum.

Internal parasites are apparently widespread in this country, except on ranges which have a very low humidity. Even there, it is difficult to find an animal that is absolutely free of internal parasites. The extension of irrigation to areas where livestock formerly was raised almost entirely on the range will create a situation, if it has not already done so, that should prove favorable to the unimpeded march of livestock parasites. Losses among sheep on irrigated pastures are already as high as, and in some areas even higher than, they are on relatively small farms in the eastern, southern, and middle western states.

Among the internal parasites of livestock which produce losses year in and year out—losses which can be curbed, at least in part, by improved management of pastures and stock—are microscopic organisms known as protozoans. These include the causative agents of coccidiosis of poultry, sheep, cattle, goats, and swine; trichomonads of practically all domestic animals and poultry; and other unicellular microscopic organisms, the pathogenic potential of which has not been adequately explored. Other injurious internal parasites include such well-known pathogenic helminths, or worms, as stomach worms of cattle, sheep, and goats; intestinal nematodes responsible for scours, emaciation, debility, and poor growth; lung worms of swine, cattle, sheep, and goats, for which no medical treatment is available; liver flukes of cattle, sheep, and goats, which occur in the Gulf Coast region and in the Intermountain and Pacific Coast states; intestinal roundworms of swine, which cause intestinal disturbance, accompanied by unthriftiness and by respiratory difficulties in young pigs when the larval worms migrate through the lungs; kidney worms of swine, which are swallowed with grass but which attack the host aggressively by boring through its skin; and other parasites about which more information is needed than we have at present. There is evidence that certain parasites, formerly limited in distribution, are spreading and becoming adapted to new environments.

Although the internal parasites which affect farm animals are transmitted from one host to another in many different ways, the most common mode of transmission is through the ingestion of the infective stages with feed (Fig. 1) and, in some cases, with water. Many of the worm parasites of livestock eliminate, from the body of the host, reproductive elements, usually in the form of eggs but sometimes in the form of larvae. These are eliminated with the excreta and, in some exceptional cases, with the urine. This is true of the vast majority of the internal parasites that live in the digestive tract of horses, cattle, sheep, goats, swine, and poultry, and of wild animals and birds. This mode of transmission applies also to some parasites that live outside the alimentary canal, in such places as the liver, lungs, and other organs which have a direct or indirect connection with the digestive tract. Parasites that localize in the kidneys, bladder, or elsewhere in the urinary tract eliminate their reproductive elements with the urine. But regardless of whether

the reproductive elements are eliminated with the excreta or with the urine, the bedding and feeding grounds of the infected animals tend to become contaminated with the seed of parasitism and thus constitute the starting points of new infections.

Life-Cycles

With few conspicuous exceptions, the reproductive elements of internal parasites eliminated with the discharges from the host are not immediately infective to the animals in which they originate or to others like them. As a matter of fact, the reproductive elements have to undergo considerable development outside the definitive host before they can invade another animal. Regardless of whether the free-living phase of a parasite involves the sporulation of a coccidial oöcyst (Fig. 2)—that is, the spontaneous division outside the host of the reproductive element of certain intestinal protozoan parasites known as coccidia—or whether it involves the development of a worm egg to the infective stage, or the hatching of a nematode egg and its subsequent transformation into an infective larva, the free-living existence of these pests affords the farmer and stockman an opportunity to attack them during the most vulnerable phase of their life by a sound regimen of hygienic pasture and livestock management. For this reason, parasitologists the world over, in studies of the life-cycles of parasites, have been shifting their emphasis more and more to the ecological relationships that exist between the extraparasitic phase of the development cycle and the environment in which this phase occurs.

Fig. 2. Sporulated oöcysts of protozoan parasites known as coccidia. *A, Eimeria arloingi; I, Eimeria intricata; N, Eimeria ninae-kohl-yakimovi* (greatly magnified).

Knowledge of the way in which animals acquire endoparasites from the environment in which they live has been accumulating gradually as a result of painstaking observations and experiments. Once the notion that worm parasites originated *de novo* from the humors of the body had been abandoned, biological investigators began discovering, in rather rapid succession, a series of amazingly intricate channels that were sometimes followed by parasites in bridging the gap between one host and another. In the case of some parasites, this gap was found to be deep and tortuous, involving an alternation of the vertebrate with one or more invertebrate hosts to complete the life-cycle. In the vast majority of cases, however, there was discovered a more or less direct life-cycle, involving merely an alternation of free-living and parasitic phases in the completion of the entire development.

Fig. 1. When the grass is contaminated with infective larvae, the sheep acquire parasites.

Although grass and other forage were suspect, for a long time, as sources of infection of animals with worm parasites, many of the ideas that took root among workers in the field of parasite investigations were based on conceptions that proved to be partly or entirely erroneous. A common erroneous conception, which persisted for a long time and which is still sometimes found in current writings, was that water was the all-important factor

in the transmission of nearly all of the health-damaging worm parasites of livestock. This misconception apparently stemmed from the knowledge of the life-history of the liver fluke. This cycle was one of the earliest and at the same time one of the most complicated of the life-cycles of parasites of farm animals. It was elucidated about 75 years ago.

The liver fluke, known to zoologists as *Fasciola hepatica,* occurs in cattle, sheep, and other ruminants. In its early stages it is adapted to an aquatic life, and it must be regarded, therefore, as an aquatic animal. Living at first as an egg in water, it hatches into a free-swimming larva, known as a miracidium, which penetrates into certain aquatic snails. There it undergoes a series of profound morphologic transformations and, by a special process of reproduction, increases enormously in numbers. Each of the resulting forms emerges from the snail as a small, tadpolelike organism, known as a cercaria, still adapted to an aquatic existence, and finally becomes encysted as an infective larva, or metacercaria, on the surface of aquatic vegetation or floats as a cyst on the surface of water (Fig. 3). The knowledge of this life-cycle, involving water as an essential medium, was carried over in one way or another to the conceptions of the life-cycles of other parasites, including nematodes of sheep.

As an illustration of the false notions that prevailed in this country before the U.S. Department of Agriculture began its systematic investigations of livestock parasites, the following facts, taken from the *Report* of the Commissioner of Agriculture of the United States for the year 1883, may be cited. While investigating an epizootic of parasitic disease of sheep in Texas, of which the common stomach worm and probably related nematodes, which have a strictly terrestrial, free-living existence, were the principal incitants, Detmers (*1*) concluded erroneously that as long as flockmasters and sheepherders permitted their sheep and lambs to drink the stagnant water of pools, waterholes, hog wallows, and other wet places, and to eat aquatic plants growing in or near such pools and waterholes, the propagation and continued existence of parasites were assured. This investigator concluded, moreover, that the animals which be-

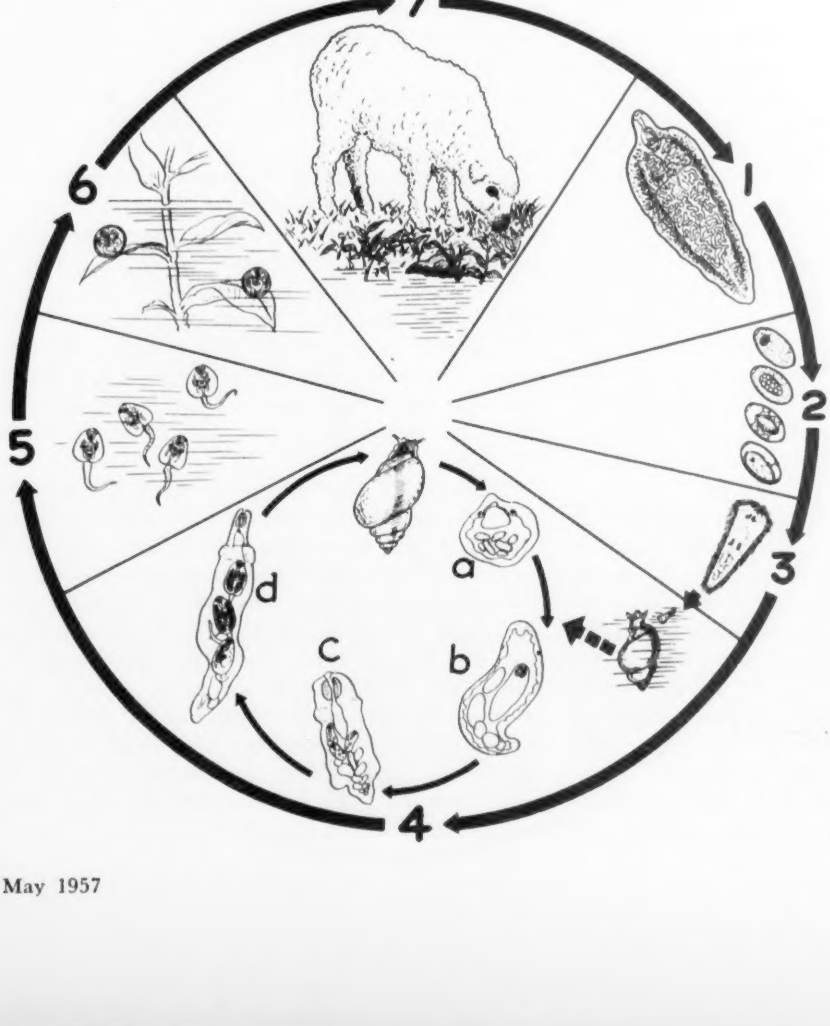

Fig. 3. Life-cycle of the sheep liver fluke, *Fasciola hepatica.* 1, Adult fluke in the liver; 2, developing eggs; 3, free-swimming miracidium; 4, extreme right, miracidium moving toward the snail intermediate host; 4*a*,-*b*, *c*, *d*, successive development stages of liver fluke in snail; 5, free-swimming, tailed cercariae; 6, encysted metacercariae on aquatic vegetation; 7, sheep eating contaminated vegetation, thereby acquiring liver flukes.

came affected with parasites must have grazed on pastures containing numerous hog wallows and low, wet places, and he regarded these as being essential "to preserve the worm-brood if once deposited."

Ransom's Work

The essential facts in the life-cycle of certain sheep nematodes, which still constitute one of the great hazards to successful sheep husbandry in many parts of this country and elsewhere in the world, were not definitely determined until about 1906. In that year, Ransom (*2*), a parasitologist in the former Bureau of Animal Industry of the U.S. Department of Agriculture, made known for the first time the essential facts in the life-cycle of the common stomach worm, *Haemonchus contortus*, probably the most injurious of all the roundworms that affect sheep and other ruminants.

At the time that Ransom began his investigations, it was already known that the adult stomach worm lived and carried out its reproductive activities in the fourth stomach and, occasionally, also in the upper part of the small intestine. Ransom reported that each female worm produced thousands of microscopic eggs, which passed out of the alimentary canal with the droppings. In a few hours or a few days, and sometimes in a longer period, depending on whether the temperature of the environment was high or low, the eggs hatched, and the small larval stomach worms developed into their final, or infective, stage. This required a few days or weeks; the length of this period, too, depended on the temperature of the environment. The development, Ransom observed, took place in the droppings, on the contents of which the young worms were living. Once they had reached the infective stage, the worms were found to have developed a marked resistance to freezing and drying, factors to which they succumbed rather quickly during the period of their development in the droppings.

Ransom determined, further, that when they had reached the infective stage, the larvae became very active and began to climb upward on the grass, provided that the air temperature was above 40 degrees Fahrenheit and that the relative humidity of the air was at a maximum. At temperatures below 40 degrees Fahrenheit, the larvae became inactive. They became inactive, also, when the relative humidity decreased, with consequent evaporation of the moisture from the surface of the grass blades on which they had climbed. While they were inactive on grass or other objects, they tended to become coiled, and remained so until moist weather, resulting from dew, rain, or fog, returned. Then they resumed their crawling—actually wriggling—activity on grass blades and attained a position which more or less assured, or certainly favored, their being swallowed by grazing sheep and other ruminant animals.

Ransom also transplanted grass to pots and placed on the grass roots a culture rich in infective larvae. He observed that, after the pots had remained a few days under a bell jar, which resulted in the saturation of the atmosphere with moisture, the grass blades in the pots were swarming with larval worms. Under pasture conditions, these worms, on being swallowed, continued their development in the fourth stomach of the host and reached reproductive maturity there in the course of 2 or 3 weeks.

This mode of development, involving the incubation of the eggs outside the host, their hatching there, and the morphologic transformation of the larvae to the infective stage after two successive molts, has been found to be typical of the mode of development of strongylid nematodes as a whole (Fig. 4).

Actually, Ransom's studies on the life-history of the common stomach worm, presented in a rather modest series of articles (*2, 3*), the first of which was published in 1906, constitute one of the important advances in the development of our knowledge of livestock parasitology. These studies pointed up the importance of grass in the life-history of strongylid nematodes. The larvae were found to be capable of climbing on objects other than grass, provided they were in a film of moisture, and they readily climbed up the sides of glass jars and bottles, in which they could be rather easily cultured in the laboratory. The marked tendency they exhibited to move upward on vegetation pointed up an adaptation that placed them in a position favorable to being swallowed by the host and, therefore, favorable to the completion of their life-cycle.

This mode of development, outlined in Ransom's pioneer work on the common stomach worm of ruminants, has since been found to be the usual pattern of development of strongylid nematodes as a whole. In some cases, the pattern showed slight deviations and modifications. Especially important was the determination that two molts occurred during the free-living development cycle, a fact of which Ransom appears not to have been quite certain. The first molt may take place within a day or so after hatching, the second one a day or more thereafter; this interval depends on the prevailing temperature. Ransom noted that the infec-

tive larva did not feed and that the cells of its intestine were laden with food granules from which, apparently, it derived its energy. He noted, also, that whereas the skin, or sheath, of the first molt was discarded, that of the second molt was retained. This sheath apparently provided additional protection to the worm against inimical environmental influences.

Another important deviation from the typical strongylid life-cycle here described is the ingression of larvae into the host by penetration of the intact skin. Such larvae undergo the typical development in the open, as already described. They have the capacity, however, of penetrating the skin through the hair follicles. They reach a small venule and thus get into the venous system and, from there, get to the heart. From the heart they reach their preferred location, chiefly through the circulation.

Let us summarize the facts here outlined: to assure the continuous merry-go-round of livestock parasites, the following conditions have to be fulfilled: (i) infected animals must be present on a pasture to contaminate it with the parasite eggs; (ii) adequate moisture and a sufficiently high temperature are required for the incubation of the eggs, the hatching of larvae therefrom, and the transformation of these juvenile, preinfective worms into infective ones; (iii) suitable host animals, to swallow larval-laden grass, must be available; and (iv) the host animals have to be in the physiological state designated as "susceptible" to permit the larvae to develop into adult, egg-producing worms. When all of these conditions are at their optimum, internal parasitism tends to assume an increasingly important role as a health factor in farm animals, often with serious, if not disastrous, consequences.

Importance of Humidity

It is well known that in areas which have adequate and well-distributed rainfall during the growing season, with many cloudy days, when the atmosphere is saturated with moisture, parasitism can pyramid to great heights within a matter of weeks (*4*), provided that the temperature is favorable. In the United States, the spring, summer,

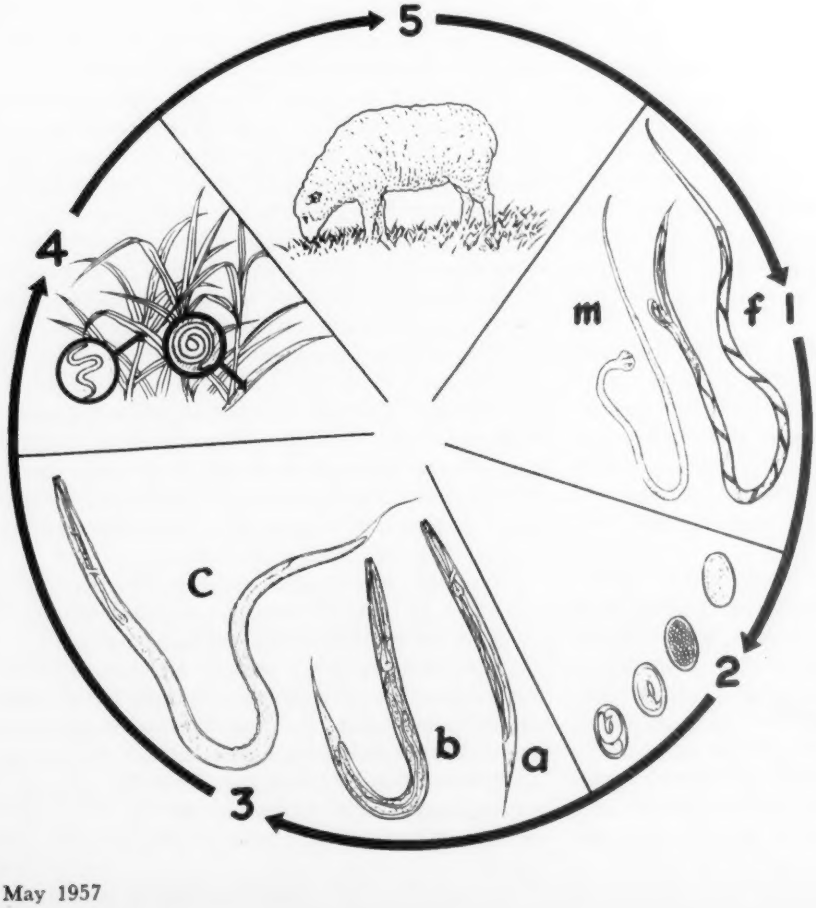

Fig. 4. Life-cycle of the sheep stomach worm, *Haemonchus contortus*. 1, Adult worms from abomasum, or fourth stomach, of sheep (*m*, male; *f*, female); 2, developing eggs on pasture; 3, free-living larvae on pasture (*a*, *b*, first- and second-stage larvae, respectively, *c*, third-stage or infective larva); 4, infective larvae on grass blades; 5, sheep swallowing contaminated grass, thereby acquiring stomach worms.

and early fall are the seasons when pastures, in places where adequate moisture is present, may be literally teeming with nematode larvae. The larvae can be easily recovered in large numbers from grass clippings taken in the morning, when the vegetation is still moist. On Kentucky bluegrass pastures on which Thoroughbreds were grazing, parasitic nematode larvae were recovered in almost every handful of grass during the months of May and June.

In the semiarid regions of this country—New Mexico, for example—internal parasites constitute a minor problem at most, or no problem at all, because the nematode parasites of cattle and sheep cannot undergo their extraparasitic development under the conditions of low humidity that prevail on the range. The number of stomach worms found in range sheep in New Mexico, with its dry soil and the dry surface of its forage plants, is limited to a few per animal, at most, except on irrigated pastures. The small number of worms that manage, in one way or another, to perpetuate themselves in sheep on semiarid ranges may occasionally increase, however, to a point where they constitute a serious danger to the health of sheep grazing there. This can happen not only through irrigation practices but also as a result of abnormally heavy rains.

One such occurrence, reported by Kemper and Cobbett in 1943 (*5*), shows that even in semiarid regions stockmen have no absolute security against the inroads of parasites. Kemper and Cobbett reported many deaths among sheep, in one instance 125 out of a flock of 800 ewes. The affected animals showed an extreme anemia of the visible mucous surfaces; some of them were almost chalky white as a result of the loss of blood due to the repeated punctures made by the stomach worms on the mucous surface of the fourth stomach. Other animals had an edematous swelling of the lower jaw, the so-called "bottle jaw" or "poverty jaw," which is also symptomatic of stomach worm and of some other worm infections of sheep. At autopsy, the blood of the affected animals was thin, had a watery consistency, and was light red in color.

This sudden and unusual eruption of a severe parasitism, with many fatalities, was brought about, according to Kemper and Cobbett, by an abnormally heavy rainfall in the summer and fall of 1941 on some of the usually semiarid range lands. Moisture was prevalent more or less continuously throughout the growing season, to an extent sufficient to produce a luxuriant growth of range grasses and to enable the nematode larvae, which came from eggs that had been eliminated by the lightly infected sheep, to hatch, develop, and climb on the range grasses. Although these animals were apparently able to maintain a good state of health, despite their parasite load, as long as the range grasses were abundant, they quickly declined in vigor in the spring of 1942 as a result of malnutrition. At that time, there was a severe drouth on the same range lands which had formerly supplied an abundance of grass. The scarcity of feed and the consequent decline in the physical condition of the animals lowered their resistance to the numerous parasites they harbored. This, according to Kemper and Cobbett, produced the severe morbidity and mortality losses that they reported.

Parasite Control

It is not surprising that when facts such as these became well established, efforts were made to devise parasite-control systems based on pasture-rotation schemes which were designed to prevent the host animals from ingesting larva-contaminated forage. Unfortunately, the grass-growing season is also favorable to the development of parasite eggs and larvae. The rapidity with which parasites develop during warm weather makes it practically impossible to rotate stock fast enough to keep ahead of the emergence of infective larvae.

Even before the facts about the mode of development of strongylid nematodes became known, efforts had been made in this country to raise lambs free of nodule-producing worms, when the ewes were infected and were passing these worm eggs with their droppings. Under experimental conditions, Dalrymple (*6*) succeeded in doing this by his "bare-lot" method. This involved raising the lambs and infected ewes together on bare lots. The absence of grass apparently deprived the larvae of a factor essential for their transfer to the host. Unfortunately, the bare-lot method did not prevent infestation with stomach worms, and it certainly was not a practical method of rearing lambs. Recent development in zero grazing (the feeding of grass-clippings) offers a much better preventive procedure than any other so far devised.

The parasites can best be checked by preventive measures, for most of them are ingested with grass or other forage. Rotation of stock and of pastures, vacating of pastures for periods adequate to insure the destruction of parasite eggs and larvae, and similar management procedures designed to widen the gap between infective parasites and their hosts, are indicated control measures. Their precise application, however, in relation to the different kinds of parasites which can attack farm animals and

under the diversity of ecologic conditions that exist in different parts of the country, still remains to be determined.

Although studies are in progress in many parts of the world, including the United States, on the influence of different types of pasture forage on the larvae of nematode parasites at the various stages of their free-living existence, knowledge of this subject is still meager. Taylor (*7*), in England, found that larvae tend to accumulate more abundantly on leguminous plants than on grass, because the under surface of the legume leaves provides protection against the deleterious action of sunlight on the larvae. In Mississippi (*8*), 5 times as many nematode larvae were recovered from fescue (a grass of the genus *Festuca*) pastures as from ryegrass pastures. Although the fescue pastures were grazed from December to April, larvae were found in clippings in August. Apparently the clumps of green fescue provided a favorable environment for the persistence of the larvae.

Recent work in Georgia, as yet unpublished, showed that permanent pastures containing fescue and crimson clover on Bermuda sod yield more larvae per pound of forage than temporary pastures of oats and ryegrass. These observations substantiate previous findings (*9*), in the same location, in which the average larval recoveries during winter grazing were 415 per pound of fescue, 48 per pound of crimson clover, and 28 per pound of temporary forage. In the course of this work, the greatest larval recoveries were made in March, April, and May, when the average temperatures were between 55 degrees and 67 degrees Fahrenheit. The highest recovery was made about the middle of April, when 1476 larvae were obtained per pound of fescue forage. More or less recent work has shown that a majority of the larvae tend to be distributed on the lower part of the plant (*10*), and that progressively fewer and fewer occur in the upper portions. Apparently the larvae accumulate in those parts of the grass where there is the least fluctuation in temperature and where the moisture content affords optimum conditions for the worms.

More Knowledge Needed

A problem that requires much more investigation than it has received so far is that of overstocking. Although this practice is usually condemned, little specific information is available about the factors that operate on an overstocked pasture. It is true that, with continued overstocking, the amount of nutriment per animal is decreased. Also, closely connected with the question of overstocking and consequent increased larval contamination of pastures is the type of forage that is being grazed. If the forage is short, or if it forms clumps close to the ground, the animals must cover a relatively large area and graze closely. This may result in their swallowing more larvae than they would if more abundant grazing were available. However, one good thing about short forages is that they afford less protection to the eggs and larvae against sunlight and consequent drying than do the longer forages.

Taylor (*11*) reports an interesting observation made in England, in 1950, with reference to intensive grazing of sheep on a comparatively poor farm. Despite intensive grazing because of overstocking, the animals were in good health. The explanations Taylor offers to account for this anomalous situation are as follows. The lambs were exposed to an onslaught of parasites very early in life. They probably developed a strong resistance to them at an early age and thereby escaped their injurious effects. The older sheep, which presumably had a high degree of resistance to parasites to be able to survive under such seemingly unfavorable conditions, collected a large proportion of the infective larvae and destroyed them, thereby leaving fewer to infect the more susceptible lambs. Finally, because of the close grazing, down to the very soil, the eggs and preinfective larvae had comparatively little protection against drying, with the result that many of them undoubtedly were destroyed.

Although there is already available a considerable amount of raw data on the effects of sunlight of various degrees of intensity, of moisture, and of other environmental factors on the vitality of the eggs and preinfective larvae, on their development to the infective stage, and on the persistence of the latter on different types of pasture, what we have is still, in the main, largely an accumulation of empirical observations. Inasmuch as the pasture is the source of most of the parasitic infections of farm animals in temperate climates, the study of the ecologic relationships of parasites to the environment is essential to an understanding of the factors that influence their life during the period when they are in the open. At no other time are they more susceptible to control, or even to eradication.

How to attack the seed of parasitism while it is still on the pasture, what chemicals (if any) or other means to use to bring about the destruction of the eggs and larvae, are problems which have not been adequately explored. We still know too little about the role of acquired immunity in holding in check or destroying parasites which are

already present in the host and in preventing others from getting in. Although it has been observed that affected animals, sometimes very sick ones, retain the parasites they have acquired, or a large proportion of them, as immature worms, the factors that operate to bring this about are unknown. In addition, how to produce resistance in hosts by methods other than natural or experimental infection with parasites and how to step up resistance to parasites, once it has developed, are still challenging problems to the investigator of livestock parasitology.

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Rare Orchid

Our cover this month shows a prized Philippine species of orchid. It is a favorite parent plant for several valuable hybrids such as the famous Vanda Nellie, which has sold as high as $1500 for one plant. This species has a dominant and pleasing shape but has a recessive coloration; hence, a variety of color can be introduced by cross-breeding.

This "shadowless" rendition was obtained by use of north sky light. This trick is often used by photographers when they have to work with a complicated shape, like this cluster of blooms. The photograph, entitled "Waling-Waling," was taken by Jose C. Mendiola, Department of Health, Manila, Philippine Islands. It was one of four award winners in the 1956 exhibition of the Biological Photographic Association. The four winners were selected from approximately 400 entries in five categories received from medical and scientific photographers in the United States, Puerto Rico, Canada, England, and the Philippines. The Biological Photographic Association was founded at Yale University in September 1931 as a national organization of scientific photographers concerned with the techniques and applications of photography in medicine, zoology, botany, and other related fields.

Global Distribution of Strontium-90 from Nuclear Detonations

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THE properties that make strontium-90 (Sr^{90}) the most hazardous of the nuclides formed in the fission process are its long half-life (28 years) and its chemical similarity to calcium. Because of its resemblance to calcium, Sr^{90} may be assimilated by biological processes. If strontium is ingested by human beings in food or water, it will deposit, like calcium, in the skeleton.

Investigation of the potential hazard from contamination of soils and the biological food chains by Sr^{90} began very early in the United States atomic energy program. The first studies, associated with the wartime weapons-development program, were theoretical and were designed to identify the principal parameters which influence the long-range effects of nuclear detonations. It was clear, from the start, that studies of radioactive fallout, and of the ultimate fate of Sr^{90} in particular, would require the application of knowledge from a wide assortment of the physical and biological sciences. The initial theoretical studies provided a valuable basis for the experimental approach to the problem that became possible with the programs of weapons testing that began in 1948 and have continued intermittently to the present time.

The Sr^{90} studies have increased in scope and complexity, and the over-all program has, for some years, been global in extent, involving physical, chemical, and biological investigations on land, in the oceans, and in the air. Known as Project Sunshine and directed at a full understanding of the physical and biological behavior of the Sr^{90} produced in nuclear detonations, these studies are concerned with an unprecedented variety of scientific questions. From the standpoint of its vast geographic dimensions and the variety of scientific mechanisms involved in the investigation, Project Sunshine rivals the most comprehensive scientific studies ever undertaken.

The factors that influence the behavior of Sr^{90} begin in the complex physics and chemistry of the fireball and the mushroom-shaped cloud which forms after a nuclear detonation. The height of the burst above ground, the nature of the terrain, and the particle size of the soil and debris sucked into the fireball, all influence the fallout pattern.

When the particles descend to the earth's surface, they leave the domain of the meteorologist and become involved in the physics, chemistry, and biology of the soil. How soluble is the Sr^{90} in fallout? Does it leach from the soil? At what rate is it incorporated into plants, and how can this rate be expressed quantitatively as a function of type of soil and type of plant? These are a few of the questions that have been studied in tracing the Sr^{90} into the first of the biological links in the food chain between soil and man. The answers to these and many more questions have been obtained by many investigators working in many laboratories throughout the country.

From its formation in a nuclear detonation until it is metabolized by man, the path of a Sr^{90} atom is long and tortuous. Understanding of its route has come from studies which know none of the bounds of any one of the conventional scientific disciplines. The phenomenology of Sr^{90} in fallout can be described only in the combined languages of all the principal combined sciences: geophysics, physical chemistry, biophysics, and biological chemistry.

In this discussion (*1*) an effort is made to present the state of knowledge in such a way as to emphasize only those portions of the over-all Project Sunshine studies that are concerned directly with an estimation of the human hazard from Sr^{90}.

In so doing, many interesting and important scientific questions are deliberately bypassed. Where a pertinent question cannot be answered because of insufficient knowledge, the most conservative possible assumptions are made, thereby tending to yield results which define the upper limit of the potential hazard.

Libby, (*2, 3*) has recently reported on the many ramifications of Project Sunshine. He has called attention to the physical and biological concepts which serve as the basis for the approach taken in the Sunshine studies and has presented a thorough evaluation of many of the data.

World-Wide Deposition of Fallout

The basic procedure for documenting the global fallout of radioactivity is by means of a network of monitoring stations which have been operated in the United States and abroad since 1951. Until recently this network consisted of 88 stations, located in 46 countries and territories. During the past few months, the network has been augmented by a number of stations sponsored by various additional governments in cooperation with the U.S. Atomic Energy Commission. The data from this monitoring network have been periodically summarized (*4, 5*).

The monitoring technique is a simple one which consists of exposing a 1-square-foot cellulose ester film covered with an adhesive. The radioactivity in fallout is largely in particulate form, and the dust is collected by impaction against the adhesive surface. The coating is insoluble and retains its adhesive properties when wet, so that in rain the radioactive dust particles are retained by the collection surface. These films are exposed in duplicate for 24 hours, after which the film is mailed to a central processing facility at the AEC Health and Safety Laboratory in New York. Most of the stations are located at meteorological observatories where the collection routine can be easily fitted into the schedule of observations and duties.

From 1951 until the latter part of 1955 (the period covered by this report), it was a relatively simple matter to determine the age of the mixed fission products collected daily by the monitoring network. At any given time the fallout was known to have originated from the most recent test series. Prior to 1954, the fallout from the detonations would diminish rapidly and would ordinarily be undetectable before the next series of tests started. This was because the yields from detonations were relatively low, and the bulk of the debris was distributed below the tropopause, where fallout is greatly hastened by precipitation and other factors.

The ease with which the age of the radioactive debris could be determined made it a simple matter to estimate the fraction of the total radioactivity that was due to Sr^{90}, by using the curves of relative isotopic abundance of fission products developed by Hunter and Ballou (*6*).

The detonation of devices having yields equivalent to megatons of T.N.T. produces clouds of radioactive debris which pierce the tropopause and become distributed in the stratosphere. From this relatively stable region of the earth's atmosphere, the particles descend slowly, and fallout to the earth's surface occurs over a period of time which is measured in years rather than in weeks or months. The traces of relatively old debris from high-yield devices become mixed with the debris of subsequent detonations. This being the case, neither the decay characteristics of a sample nor the relative abundance of the long-lived isotopes can be predicted from theory.

Late in 1955 it became apparent that it was increasingly difficult to predict the Sr^{90} of fallout from theory, because of the mixing of debris from more than one test series. The method of estimating Sr^{90} was therefore changed. At the present time, increasing reliance is placed on direct radiochemical analyses of the contents of pots which collect the fallout continuously for 1 month. The gummed films will continue to be used as the basic collection device, because its simplicity makes it possible to obtain data from a great number of stations. Unfortunately, films cannot be analyzed directly for Sr^{90}, and it has therefore been necessary to devise other means of determining the ratio of Sr^{90} to total fission-product activity.

Calibration of these gummed films against cylindrical pots indicates that the technique has an efficiency of about 63 percent for collection of mixed fission products. The sacrifice in collection efficiency is justified by the ease with which the samples can be collected, transported, and analyzed.

The pair of gummed films present a sampling area of 2 square feet per station. Thus, the total area sampled by the network is 176 square feet, which is only 3×10^{-14} of the area of the earth. One must therefore inquire about the adequacy of the coverage provided by the sampling network and the possibility that areas of the world may exist in which the Sr^{90} deposition is very much higher than the values observed at sampling stations located hundreds of miles apart.

Table 1 provides a regional summary of the cumulative fallout of Sr^{90} reported for the collection stations. Stations in the immediate vicinity of

Table 1. Regional summary of Sr^{90} deposition as of 1 Sept. 1955.

Place	No. of Stations	Range (mc/mi^2)	Mean (mc/mi^2)
Europe and the Middle East	6	4.0–5.9	5.0
Africa	7	3.0–6.7	5.4
Japan and Southeast Asia	11	4.5–11	7.0
Australia and New Zealand	4	3.3–5.6	4.8
Latin America	12	2.9–8.3	5.4
Canada and Alaska	13	3.0–6.9	5.1
United States	22	3.4–13	7.8

the test sites in Nevada and the Marshall Islands are excluded because, as was expected, the fallout patterns in these regions are less regular than elsewhere, and the data are therefore not applicable to a discussion of global fallout phenomena.

Table 1 reveals a high degree of uniformity in the cumulative deposition of Sr^{90}. The mean of the means of the seven geographic areas is 5.8 millicuries per square mile and the range of values for the 75 stations included in the table is 2.9–13 millicuries per square mile. Only two stations in the United States (Boise and Memphis) and none of the overseas stations have values greater than twice the mean of the area means. The uniformity of the depositions suggest that it is unlikely that Sr^{90} exists in any part of the world (excluding regions near testing sites) in amounts greatly in excess of the upper values reported in the table.

Previously, Libby (3) has called attention to a band of relatively high fallout in the Northern Hemisphere. This band, which Libby attributes to the relatively rapid fallout of tropospheric debris in the latitudes of the detonations, is not as marked in the world-wide pattern of the gummed film network, although the values for the United States, Japan, and southeastern Asia are noted to be about 50 percent higher than elsewhere. In general, the values reported here for the Southern Hemisphere are higher than those reported by Libby, but the differences are of little significance in the ultimate estimates of the potential human hazard.

In October 1955, 17 samples of soils were collected in the United States at places where the adhesive films had been in use since 1951. This study, which has been previously reported (5), indicated that the measured values of strontium in soil were on the average 1.6 times the estimates based on film collections. It was noted that this relationship did not hold for sampling locations situated near the Nevada test site, and it was tentatively concluded that the relative enrichment of Sr^{90} in the soils at a distance from the test site was due to the fractionation of Sr^{90} in the early development of the radioactive cloud. Perhaps it is due, instead, to peculiarities of the desert soils of that region.

More recent analyses of soils at a number of overseas locations have not indicated a clear-cut relationship between the estimates of fallout derived from soil analyses and from adhesive films. In Fig. 1 are given the results of soil analyses from various parts of the world, as reported by the University of Chicago (7). The data are plotted against the estimated values of Sr^{90} based on predictions from the adhesive film network. In general, the estimated values are somewhat higher than the measured values. The reason for this is not understood. The obvious possibility that the Sr^{90} is leaching from the soil seems unlikely in view of other data which indicate conclusively that the bulk of Sr^{90} in undisturbed soil is retained in the upper 2 inches, and vertical leaching may therefore be said to be negligible. The possibility that the debris is washed horizontally cannot be disregarded, although this possibility seems to be ruled out by other evidence that the debris tends to remain fixed at the site of original deposition. The recovery of Sr^{90} from soils is an exceedingly difficult chemical procedure, and it is possible that incomplete recovery of the isotope may, in part, explain the discrepancy noted.

Fig. 1. Results of soil analysis in various parts of the world, as reported by the University of Chicago, plotted against estimated values of strontium-90 based on predictions from adhesive film network.

Although the sampling locations are relatively few in relation to the total surface of the earth, and although no data are available for the large ocean masses, the uniformity of the cumulative deposition of Sr^{90} makes it possible to estimate the total Sr^{90} deposition over the surface of the earth. The integrated total, based on the adhesive film measurements, at the end of September 1955 is estimated to have been 1 million curies, with an average deposition of 5 millicuries per square mile.

Stratospheric Reserve of Strontium-90

A complicating factor in the Sr^{90} studies is that megaton devices inject substantial amounts of fission products into the stratosphere from which depletion occurs at a relatively slow rate. Evaluation of the potential hazard from the radiostrontium produced up to any given time requires that we consider not only the Sr^{90} already deposited on the earth's surface but also that which remains in stratospheric storage and which will be deposited at some future time.

Libby has postulated (*2*) that the stratospheric reservoir is depleted exponentially, with 50 percent being removed every 7 years. More recent data indicate that this estimate may be slightly high, but the true half-time of deposition is certainly greater than 4 years.

The stratospheric residence time of the bulk of the debris is certainly short in relation to the radiological half-life of Sr^{90}. If the debris were to be stored in the upper air for a period as long as, or longer than, the half-life of Sr^{90} (28 years) the potential hazard would be significantly less, because radioactive decay would eliminate appreciable amounts of Sr^{90} before deposition to the earth's surface takes place. However, since the mean residence time in the stratosphere can be taken to be much less than 28 years, only a small fraction of the Sr^{90} will decay before it is deposited on the earth's surface. One can therefore estimate the ultimate deposition of Sr^{90} by assuming that this nuclide is uniformly mixed in the stratosphere and that the total amount now stored in the stratosphere will be deposited uniformly on the earth's surface. Whether this deposition will be complete in 5 years or in 10 is of minor importance in estimating the potential hazard to be expected.

It is possible to sample the stratospheric dust burden, and a number of measurements have been reported by British and United States investigators (*8*). Both groups have collected samples of dust by filtering air, using aircraft up to about 45,000 feet. In addition, the United States has flown constant level balloons up to 100,000 feet and has collected dust samples by electrostatic precipitation as well as by filtering air. The data obtained in these studies indicate that the stratospheric Sr^{90} is present in approximately the expected amounts, but there are, at the present time, insufficient data to permit reliable estimation of the total stratospheric reservoir of Sr^{90}.

A better estimate of the stratospheric reserve can be obtained at present from material balance studies. The amount of Sr^{90} produced in detonations, to date, can be estimated with some certainty. Estimates of the amounts of Sr^{90} that are deposited in the intense fallout in the vicinity of a detonation are available from extensive investigations conducted during the test programs in Nevada and in the Pacific. The total strontium produced in a detonation, less the Sr^{90} which falls out in the immediate vicinity of the detonation, gives the total inventory of Sr^{90} that is available for subsequent deposition at places remote from the site of detonation.

Based on this approach, it is estimated that the present stratospheric inventory of Sr^{90} from detonations to the present time is about 3 times the total amount that has already been deposited outside of the United States. In the United States, Sr^{90} from the Nevada tests was a significant fraction of the Sr^{90} fallout at the end of 1955; hence, the proportionate increase will be less in the future from the more uniform deposition of stratospheric debris.

The probable average level of world-wide contamination by Sr^{90}, when all of the Sr^{90} produced to date has been deposited, may be approximated as about 20 millicuries per square mile, by adding 15 millicuries per square mile to the average deposition of 5 millicuries per square mile at the end of 1955. This estimate, based on data from the adhesive film network, is in good agreement with Libby's recent (*3*) estimate of 15–17 millicuries per square mile.

Significance of Strontium Levels in Soil

The deposition of Sr^{90} in soil must be related to assimilation by biological processes and to absorption by man. The presence of this isotope in soil is significant only because it is potentially available for assimilation by plants, animals, and ultimately man.

To define the potential risk from a given distribution of Sr^{90} on the surface of the earth requires that the distribution be quantitatively related to the skeletal burden of Sr^{90} of a human population in dietary equilibrium with the soil from which its nourishment is derived. This equilibrium is already established for a variety of trace elements normally

present in the earth's crust. Some of these, like potassium and radium, are radioactive, and this is reflected by the presence of these substances in the human body. For example, the upper foot of soil in the United States contains, on the average, about 1000 millicuries of radium per square mile. The average adult skeleton in this country contains about 10^{-4} microcuries of radium, which is derived from assimilation of this trace element from foods and water. Thus, the value of 10^{-4} microcuries of radium represents the amount deposited in the skeletons of the populations whose mineral metabolism is in equilibrium with the soil minerals.

The freshly deposited Sr^{90} takes a relatively long time to complete the biological route to bone. At the present time the skeletons of all but very young children were formed prior to the introduction of Sr^{90} to the soil. Moreover, bone being formed at the present time utilizes calcium which left the soil in months gone by. The fact that cattle may be fed on hay many months old and the hold-up of human foods in the commercial distribution system are but two of many factors which would lead one to expect the human Sr^{90} burden to lag in time behind the potential value which might ultimately be expected from a given soil concentration. The human skeleton cannot be expected to respond quickly to the gradual accretion of Sr^{90} by soil. Equilibrium can be expected to be achieved over a period of years but not over a period of months.

In the United States, as in a number of other parts of the world where the population derives much of its calcium from dairy products, analyses of milk for Sr^{90} provide a method of estimating the levels of human absorption which may be expected in the future.

Recent studies by Comar (*9*) have suggested that when radiostrontium is incorporated into milk there is less biological differentiation between calcium and strontium than is otherwise expected from nonmilk diets. The effects of nonmilk substances on behavior of milk calcium and the over-all discrimination between strontium and calcium in man under varying conditions are not yet known. As the most conservative assumption, one may consider that when a skeleton is formed by calcium from dairy products, the skeleton will contain the same strontium-90–calcium ratio that was present in the food. Evidence is becoming available that over-all discrimination will favor the retention of calcium over strontium in the body. When adequate results on this point become available, the estimates in this article for predicted dose to the skeleton can be revised downward.

Milk from the metropolitan New York milkshed has been sampled regularly since early 1954. In 1955 the sampling program was expanded to include other milksheds, in the United States and abroad. The Sr^{90} content of the New York milk is presented graphically in Fig. 2, and Table 2 gives the average value for all sampling locations during the first half of 1956.

Since Sr^{90} is not a natural constituent of the earth's crust, it follows that the presence of this isotope in biological materials is due to fallout from the detonation of nuclear devices during the past few years. Insufficient time has elapsed to reveal whether or not the concentration of Sr^{90} in milk bears a linear relationship to the accumulating Sr^{90} in soil. The value of between 2 and 3 micromicrocuries Sr^{90} per gram of calcium, representing the average range of values reported from mid-1955 to mid-1956, can be explained in two ways, both of which involve contamination of the cattle feed. This contamination may occur by way of the soil, in which case the Sr^{90} is incorporated metabolically into the feed, or the contamination may exist as freshly deposited fission products on the surface of the plant.

If the contamination in milk results primarily from the latter factor, it would be expected that a cessation of nuclear detonations would be reflected in a diminution of the Sr^{90} content in the coming years, as the stratospheric inventory of Sr^{90} becomes depleted and the fallout onto the surfaces of the feed becomes correspondingly less. On the other hand, if the contamination of milk is due primarily to the Sr^{90} incorporated metabolically from the soil, the concentration in milk would be expected to increase in proportion to the Sr^{90} in soil. The maximum concentration in milk would be reached after the stratospheric reservoir has been deposited in the soils.

It will be noted from Fig. 2 that a steep rise in Sr^{90} content occurred in the metropolitan New York milk supply in early September 1956. It is not now known whether this rise is due to the relatively heavy fresh fallout from foreign detonations conducted last summer or to an increase in the amount of Sr^{90} incorporated metabolically from the increasing amounts of Sr^{90} in the soil. If the former hypothesis is valid, the milk concentration can be expected to diminish in succeeding weeks. If the increase is sustained, it is presumably a reflection of the increasing amount of Sr^{90} in soil. As a basis for comparison with the soil values, the curve of cumulative Sr^{90} in the New York area is superimposed on the milk curve. It will be noted that, since 1954, the cumulative fallout of Sr^{90} is increasing steadily with time, but even if one accepts the recent increase in the Sr^{90} content of milk, the latter is at a much slower rate.

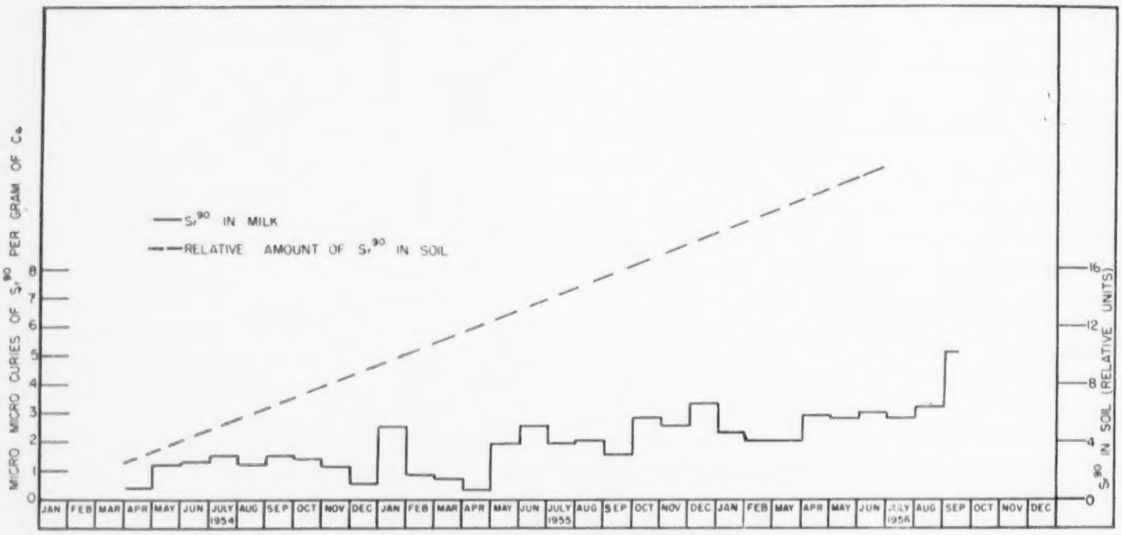

Fig. 2. Relative concentrations of strontium-90 in milk and in soil in the New York area.

The deposition of Sr^{90} in the soils of the metropolitan New York milkshed in the early fall of 1955 is estimated to have been 6.5 millicuries per square mile. The expected maximum in this area is thus 21.5 millicuries per square mile when the stratospheric inventory of Sr^{90} is deposited. This is an increase by a factor of 3.3. In the summer of 1955 the milk in this area averaged 2.5 micromicrocuries ($\mu\mu c$) per gram of calcium (Ca). If we assume that the milk concentrations will increase in proportion to the soil content of Sr^{90}, the maximum value that can be attained in metropolitan New York milk of the future, from detonations to date, is about 8.3 $\mu\mu c$ Sr^{90}/g Ca. It should be again noted that this is a conservative assumption which ignores the possibility that much of the Sr^{90} in milk may be ingested by the cows as fresh fallout on the surface of plants. If we further assume that no differentiation between strontium and calcium will occur in the process of converting milk to human bone, 8 $\mu\mu c$ Sr^{90}/g of skeletal calcium becomes the upper limit of the foreseeable strontium burden in the population of this area from detonations which have already occurred. A factor of 3 should be ample to define the upper limit of hazard elsewhere in the United States where, as in North Dakota, the Sr^{90} uptake is proportionately higher than in metropolitan New York. On this basis, 25 $\mu\mu c$ Sr^{90}/g Ca is the highest foreseeable skeletal burden in the United States. This estimate is likely to be reduced as new information about the uptake of Sr^{90} eliminates some of the uncertainties which have prompted the use of highly conservative assumptions. Although this estimate is higher than Libby's recently estimated upper value of 10 $\mu\mu c$/g Ca, the agreement is excellent considering the fact that the two estimates are based on different approaches and that both are deliberately conservative.

The data from the world-wide fallout collection network indicate that the fallout is distributed, throughout the portion of the world that has been sampled, in a remarkably uniform manner. If the potential strontium hazard in an agricultural area anywhere is greater than in those areas in the United States for which the milk data in Table 2 serve as indices, the reason is likely to be found in the soil chemistry of the region or in the dietary habits of the people.

There is good evidence that the uptake of Sr^{90} is markedly influenced by the amount of calcium available to growing plants. For any given amount of Sr^{90} in soil, the uptake into plants will vary inversely with the available calcium present in the soil. Plants growing on soils which are depleted in calcium assimilate more Sr^{90} than otherwise.

The manner in which differences in the dietary habits of populations influence the Sr^{90} uptake requires further study. Leafy vegetables can be expected to have a higher ratio of Sr^{90} to calcium because of direct deposition on the surface of the leaves. For example, in a crop of snapbeans grown in Maryland in the summer of 1956, the leaves assayed 78 $\mu\mu c$ Sr^{90}/g Ca, whereas the beans assayed only 2.2 $\mu\mu c$ Sr^{90}/g Ca. Since it is doubtful that any differentiation between strontium and cal-

cium occurs metabolically within the plant, the difference is presumed to be the result of distribution of fresh fallout on the leaves.

Two methods are available for quickly screening populations to determine whether any unusual factor or combination of factors is contributing to a higher Sr^{90} uptake. Although the sampling of human bones is of limited value in assessing the Sr^{90} burden which may be expected when an equilibrium is reached, the method is satisfactory for comparing populations at any given time. Kulp and Eckelmann (*10*) have recently completed several hundred analyses of human bones from various countries of the world and find little difference between one area and another, except that United States values, on the average, are higher than those which they found elsewhere in the world. They report an average of 0.35 $\mu\mu c$ Sr^{90}/g Ca in bones of children in the eastern United States at a time when the milk assayed almost 10 times as high.

Another screening method which appears promising is the analysis of pooled urine samples. Only a few data are available, but it is known that Sr^{90} is detectable in the urine of individuals in the eastern United States. The level in early summer of 1956 was about 1 to 2 disintegrations per minute per liter. In a population in which the dietary intake of Sr^{90} is relatively uniform, the Sr^{90} excretion can perhaps be used as a measure of the Sr^{90} intake. Additional data should be obtained for other parts of the United States and for other countries as well.

Hazard of Strontium-90 in Bone

The foregoing reasoning suggests that a maximum of 25 $\mu\mu c$ Sr^{90}/g Ca is foreseeable in human bones perhaps a decade hence when biological equilibrium is reached with the Sr^{90} produced up to the present time. This figure is arrived at by making the deliberately conservative assumption that the presently observed values of Sr^{90} in milk represent the equilibrium values between milk and soil. and that henceforth the milk concentration of Sr^{90} will bear a linear relationship to the deposition of Sr^{90} in soil. It is further assumed that the human body does not differentiate between strontium and calcium and that the specific activity of skeletal calcium will therefore be equal to the specific activity of milk calcium. The value of 25 $\mu\mu c$ Sr^{90}/g Ca may overestimate the true value by a factor of 10. Allowing for simultaneous decay of the isotope in both the soil and bone, 25 $\mu\mu c$ Sr^{90}/g Ca will deliver a dose of 2.3 reps to the skeleton over a lifetime of 70 years. This compares with a normal range of skeletal irradiation of 7 to 30 reps resulting from potassium-40, carbon-14, cosmic rays, terrestrial gamma radiation, and natural radium. The maximum foreseeable value of 25 $\mu\mu c$ Sr^{90}/g Ca, when integrated over the life-span, is thus equivalent to 7.6 to 33 percent of the dose from natural sources of skeletal radiation.

The variability of the skeletal dose resulting from natural radioactivity is largely due to differences in the body radium content, which has been shown to vary from one geographic region to another. For example, it is reported (*11*) that, in Illinois, the skeletal dose from radium alone varies between 6.7 and 67 millireps per year (0.47 to 4.7 reps in 70 years). The gamma-ray dose received externally from terrestrial sources is likewise quite variable, depending on the kinds of rocks in the vicinity.

If we take 30 reps in 70 years as the upper limit of skeletal irradiation from natural radioactivity in the United States, the skeletal burden from Sr^{90} from detonations to date could reach peak values as high as 330 $\mu\mu c/g$ Ca before the maximum skeletal dose from *natural* radioactivity would be doubled.

The National Committee on Radiation Protection recommends 1 microcurie of Sr^{90} as the maximum permissible continuous burden for occupational exposure. It is generally accepted that, for public exposure, an additional safety factor of 10 is advisable, and on this basis 1/10 microcurie of Sr^{90} would be the maximum permissible body burden for public exposure. This is equivalent to 100 micromicrocuries of Sr^{90} per gram of skeletal calcium. The conservatism of this value is illustrated by the fact that the dose delivered to the skeleton by a constant deposit of 100 $\mu\mu c$ Sr^{90}/g Ca is 20 reps in 70 years, which is somewhat less than the upper limit of dose delivered by natural sources alone. The recommended maximum value of 100 $\mu\mu c/g$ Ca, being intended for continuous

Table 2. Strontium-90 in milk, January–June 1956 (all values in $\mu\mu c$ Sr^{90}/g Ca).

	N.Y.	State College, Miss.	Madison, Wis.	Mandan, N.D.	Portland, Ore.	Japan	England
January	2.3	–	3.0	3.5	–	2.7	4.0
February	2.0	–	3.5	8.1	–	–	4.6
March	2.0	6.3	3.4	11.	–	3.5	4.0
April	2.9	6.7	3.4	7.7	5.2	3.0	–
May	2.8	4.9	2.8	10.	6.4	–	2.9
June	3.0	4.4	3.4	8.7	5.0	–	–
Average	2.5	5.6	3.3	8.2	5.5	3.1	3.9

exposure, is not directly applicable to an evaluation of the potential risk from detonations to date. The natural radioactive decay of Sr^{90} will reduce to about 0.5 the dose delivered in the lifetime of individuals who, from birth, begin to accumulate skeletal calcium initially containing 25 $\mu\mu c/g$.

Summary

The world-wide distribution of the Sr^{90} produced in weapons tests up to the present time can be expected to rise to approximately 20 millicuries per square mile in the latter part of the next decade. Because of the chemical resemblance of strontium to calcium, Sr^{90} tends to be assimilated by plants, ultimately finding its way into foods and man, where the maximum foreseeable deposition in human beings will produce a radiation dose to the skeleton that will be about 2.3 reps in a lifetime of 70 years. This estimate is based on conservative assumptions, and in all probability the actual dose will be considerably less, possibly as low as 0.23 rep. The dose in the United States from natural radioactivity, to which human beings have always been exposed, ranges from 7 to 30 reps in 70 years. The highest estimate of the skeletal dose that can be foreseen from devices detonated to date is thus 7 percent of the upper values of the dose delivered by natural radioactivity and may prove to be as little as 0.7 percent.

References and Notes

1. I am indebted to the staff of the Health and Safety Laboratory, and others, of the U.S. Atomic Energy Commission for many of the data utilized in this discussion. Many of the investigations were under the immediate supervision of A. E. Brandt, John H. Harley, Edward P. Hardy, and Ira Whitney. In addition, I profited from discussions with Lyle Alexander, C. L. Dunham, and W. F. Libby.
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Man's Place in Living Nature

H. J. MULLER

Dr. Muller, professor of zoology at Indiana University, has been a pioneer in the field of radiation genetics for more than 25 years. He won the Nobel prize in medicine in 1946 for his work in proving that x-rays can cause mutations in genes. This article is based on an address which he made at the dedication of the David Starr Jordan Hall of Biology at Indiana University on 9 June 1956. It was published in two installments in the January and March issues of the Humanist. *The present version incorporates revisions successively made in giving it as lectures at Amherst College, 8 Feb. 1957, and at the University of Alabama, 6 Apr. 1957.*

IN spite of the elaborate detail with which the Darwinian theory has been demonstrated and refined upon in our own century, and its acceptance by all unbiased students of the subject, it has not yet come to form an integral, fundamental part of the average American's way of thinking and outlook on life. It is given scant and usually skeptical attention in grade schools and even in most high schools and some colleges, and it is largely relegated, by general consent, to specialists. It is therefore up to those of us who are acquainted with this situation to do our bit to overcome this willful and dangerous blindness on the part of our fellows concerning what we ourselves are, what we came from and how, where we now stand, and where we are or should be headed and why. Otherwise we only deserve the fate of sheep, which sheeplike behavior will bring.

On Human Preeminence

In order to view ourselves in as broad a perspective as possible in relation to the rest of living nature, let us first try to get an idea of how big and important a part we form of the sum total of things now alive. Bulk is not a very meaningful measure, but we may note that in total bulk the plant life on earth necessarily exceeds the animal life enormously, since animals are in a sense parasitic on plants. As for the animal kingdom itself, most of it is aquatic, while on land the greater part, by bulk, of animals consists of the small creatures that are buried in the soil. Confining our attention to the animals living on and above the surface of the land, it is only in fairly recent centuries that human beings have come to form any considerable fraction of this material. However, our relative influence far exceeds our relative bulk today, since we have such unparalleled and rapidly growing powers of determining what other forms of life shall exist, and what the conditions of their existence shall be. Moreover, now that it is admitted even in political circles that we are on the verge of space flight, our dominion over other life forms as well as over inanimate things is on the way to being extended utterly beyond all former bounds.

This brings us up against a further question, however. Are we not being extremely provincial in looking on ourselves as the kingpins of nature when in fact in the universe at large, into whose citizenship we are attempting to graduate, we may find ourselves pitifully insignificant? That life will originate and evolve wherever the temperature, the inorganic substances, and the incident radiation are of the sorts that have existed on our earth is highly probable in the light of current geochemical, physicochemical, and biochemical studies. Supporting this inference is the recent strengthening of the evidence, derived from its color changes, that life has developed on Mars also, although on that planet nature has obviously been far less bountiful than on our earth in allowing the multiplication and evolution of life. On no other planet in our solar system but these two would conditions of planetary size, rotation, composition, and temperature have been favorable for the development of living things composed of materials like ours. It would be ultraspeculative to postulate that there could be other forms of life than those based on carbon compounds in a medium of water.

However, we must remember that our own sun is not "the only pebble on the beach." As for the myriads of other suns, the recent deduction of the presence of relatively small associate-bodies to some of the stars, near enough to allow the telltale disturbances of their motion to be detected, as well as the recent condensation theories of the origin of planets, are at last leading astronomers away from their inherently improbable view that planetary systems are only the result of almost impossibly rare

near-collisions of stars and back to the conclusion that our own solar system represents a fairly common development. Thus, since our own galaxy alone contains tens of billions of suns, and there are many millions of these galaxies of suns in our view, it is probably a very gross underestimate to say that many trillions of planets besides our own are at this moment serving as the abode of life (*1*). If we accept this inference, we must conclude that man's place in the living nature of the universe at large is a very minor one indeed, unless we are paranoiac enough to postulate that our own form of life is at the peak not only of all the species on our own planet but of those on the trillions of others as well.

Nevertheless, there can be no question that in our own little bailiwick we *are*, for the moment at least, in the dominant position. Moreover, so dominant are we that nothing else in the neighborhood will ever be able to challenge our position, provided that we keep careful watch over the living things about us and over our own natures, and wisely control those almost imperceptible processes that tend to bring about long-term major changes in them and in ourselves. Mankind will be able to meet this requirement only if people in general attain a far more acute awareness and deeper understanding than they have at present of biological realities and the mechanism of evolution. Along with this must go a sense of responsibility toward our descendants so much stronger than that of today as to motivate us even in decisions that deeply affect the entire conduct of our lives. I am optimistic enough to believe that, when people get to realize how much they have to gain by such a course, they will gradually come to adopt it. For man, more than any other animal known to us, looks behind and ahead of him, regulating his actions by an ever longer-range view. That is, as Korzybski has put the matter, man is becoming more and more a "time-binding" creature, or, as I might amend it, one that is "space-time-binding."

Some Conditions for Progression

Granted this development, and barring such a social catastrophe as nuclear war, we may, I think, look forward to an enormous period of progression and expansion. In this we need not be too troubled by the thought of interference on the part of the hypothetical inhabitants of other worlds. For even though we must concede the high probability of the presence in innumerable places of diverse exotic beings greatly excelling ourselves, nevertheless the mere fact that in the billions of years of life's existence none of them has ever arrived and become established here is enough to demonstrate the power of these vast distances in keeping us apart, not absolutely or forever, but over sections of space-time that for us are of very significant magnitude. It is invalid to object that the higher stages of biological evolution, those productive of intelligence and scientific techniques, have only in recent years been entered upon, and that there has therefore been too little time for the development of interstellar travel by higher life-forms. For the less than 100 thousand years that separate the advent of our species from our (still prospective) development of nuclear-powered rockets is less than 1/10,000 part of the period occupied by biological evolution on this earth, and the 500 years of modern science form less than a millionth part of the story. It would be simple-minded to suppose that the pace of the evolution of intelligence has nowhere else exceeded ours by as much as one part in a million. Hence the essential unity of the evolutionary tree of all terrestrial organisms, attesting to the absence of alien intrusions among them, can justify our feeling relatively secure within our own back yard, and throughout as wide a range beyond it as we can reach for a long time yet to come, if only we will cultivate both our acres and ourselves with foresight and devotion.

But the putting of this policy into practice is a task that will test our mettle. There are more than a million species on this earth, not counting the races and varieties of each, and every one of them is connected in devious and complicated ways with many of the other species, so that the pulling of a thread here may cause unexpected warpings and tearings of the fabric elsewhere. Each type of organism, moreover, is a veritable world within itself, and that is certainly true of our own biological constitution. Properly to cultivate ourselves we must know ourselves, as Socrates declared, and we must also know the surroundings, including the other organisms, in relation to which we are striving to improve our, and their, adjustments. The mass of details to be learned and dealt with in pursuit of these aims is unending while, at the same time, there are innumerable ways of combining and integrating the details. Thus many of the problems, as well as the possibilities, are "open," without single or final solutions attainable for them, but offering ample room for the continuing exercise of our creativity.

Let us try to look through the welter of details in order to discern a few of the main principles already known, of which these details represent the outgrowths. Only when we have come to recognize these principles concerning the way living things work and develop through the ages can we ap-

preciate just where we stand in relation to the rest of nature. And only then can we work out the types of strategy necessary for attaining long-range success in our management of ourselves and other forms of life.

Roots of Life's Developments

In pursuit of these objectives, we may first inquire what the most distinctive attributes of living things are, as compared with nonliving. Many different answers have been given for this, because most objects that we commonly think of as living are very complicated and differ in many ways, or combinations of ways, from natural nonliving objects. One favorite answer is to say that it is their chemical composition which is distinctive of living things. Insofar as behavior necessarily depends on structure, this statement is virtually a truism, or else it is merely a denial of a "vital spirit." But the questions must then be faced, what portions and features of this exceedingly elaborate chemical structure are the indispensable ones? and how are they changed and interfered with in a cell or organism that has just been killed in some way, as compared with a living one? This focuses attention on the fact that, even though the chemical structure serves as the basis, it is the distinctive behavior of which this structure is capable that makes it the vehicle of life. What we really want to know is, first, what (if any one or a few things) are the primary feature or features of this behavior that make possible the rest of the remarkable operations of which living things are capable? and, second, what is it about the chemical structure that gives rise to this primary peculiarity or group of peculiarities of behavior?

I believe it has become clear in recent years, especially through work on viruses and bacteria, that the most primary peculiarity of behavior of living things in general is that to which, in my discussions of 35 and 30 years ago on the gene (*2*), as well as since that time (*3*), I pointed as the attribute of behavior most distinctive of the gene as compared with other materials of living things, and as the one that justifies us in regarding the gene as the basis of life. This distinctive behavior consists in the construction by, or under the guidance of, the gene of a copy of itself, by a method that results in the incorporation within this copy even of changes—mutations—that the gene may have undergone. In other words the gene duplicates itself and does so in such a remarkable way that even its own variations become duplicated in the process. The statement that the gene duplicates its variations is after all another version of Darwin's expression, "descent with modification," that applies to living things as a whole (*4*). Thus the gene has, when in its setting, the type of behavior that results in the natural selection of inheritable variations—in other words, it constitutes the basis of the Darwinian mechanism of evolution.

For the operation of this mechanism it is not necessary for the inherited variations, or, as we shall call them, the mutations of genes, to come about by an adaptive reaction—that is, for them to have a tendency to be advantageous. In fact, abundant evidence shows that the great majority of mutations are harmful. It is only necessary (i) for mutations to be very diverse, so that occasionally a gene of a more advantageous type does happen to arise, and (ii) for the genes, or groups of genes, to be capable of accumulating mutations up to a practically unlimited degree of complication. It will inevitably follow that the rare superior type, by virtue of its greater ability to survive and multiply—which is how we define superiority or advantage, biologically speaking—will tend to succeed and increase in number, and will thereby afford a basis for the taking of further and further steps, in like manner. In consequence, a series of complications will become built up and retained that aid in the maintenance and reproduction of the whole complex.

Appurtenances Called "Protoplasm"

With the accumulation of studies in genetics and in biochemistry, there is increasing ground for acceptance of the inference that the gene's ability to duplicate itself and its mutations depends primarily, or did depend in early times, on peculiarities of its own structure, rather than on the presence of the elaborate collaborating mechanisms of protoplasm, although of course we do have to suppose raw materials suitable for the construction of duplicate genes to be present. If this primacy of the gene in its self-reproduction is admitted, we may envisage at the origin of life a virtually naked gene of the most rudimentary possible type, in a medium containing the raw materials for its own duplication. Such a medium, as Urey (*5*) and other chemists assure us, may be expected to have arisen through the action of radiation and perhaps also, to a lesser extent, of electric discharges, on the constituents of the atmosphere. With the accumulation of ever greater mutational complications in genes and cohering groups of genes of those types that were advantageous for gene survival and multiplication, the early genes would increasingly assume the role of centers of chemical activity for the construction of an organized system of acces-

sory substances that helped to insure and to speed the multiplication process and to extend it into situations in which it could not otherwise have operated.

This great system of accessory substances, or protoplasm, arising as the by-product and tool of gene action, is fundamentally alike in its multitudinous intricacies in all cellular organisms. Evidently, then, these varied species represent different branches that arose from one stem form after it had already evolved to the protoplasmic stage. But despite this fundamental similarity, the different organisms of early times embarked upon very diverse and elaborate specializations that enabled them to make use of various types of raw materials and sources of energy for their multiplication. In this way the resources available for the formation of living things became enormously enlarged, and they became freed of their dependence on the accidental accumulation of certain rare organic compounds. At the same time, some types, evolving in such directions as to make use of the organic products of others and to rework them, came to serve the community of living things as a whole in a different way. For their activities kept in circulation, for the use of organisms in general, the materials and the energy, gained by others, that were needed for the operations of life and that otherwise would have accumulated in unavailable pockets. These scavenger forms, in other words, survived by rifling these potential pockets, and thus minimized the obstructions to a free flow of biochemical exchanges. Biochemically considered, the whole animal kingdom represents one form of these scavengers, while fungi and some bacteria are other types of them.

Central Fiber

If we accept the view that biological evolution, with all the complications it brought in it its train, was an inevitable outgrowth of the gene's peculiar faculty of making copies of itself—copies that included its own mutations—then, as mentioned earlier, the second basic question arises, "What is it about the chemical structure of this gene material that enables it to act in this remarkable way?" This is not the place to recount in detail the successive phases of the attack on this problem. In the first place, through a great deal of biochemical work on chromosomes, followed by work on viruses, on plant plastids, and on the kappa bodies of paramecia, the evidence gradually became convincing that material which is capable of reproducing itself and its mutations is always composed of nucleoprotein, a compound of nucleic acid and protein. Secondly, another series of researches on bacteria and on viruses showed that the nucleic acid portion of this compound is by itself sufficient, if given an opportunity to enter into association with nonspecific protein or protein-precursors, to direct the subsequent reproduction of the material in such a way as to result in exact copies of the original nucleoprotein, as a whole, from which that nucleic acid alone had been taken. This seems to make the protein secondary and ties the primary faculty on which life depends to the nucleic acid, which is in the form of a fiber or chain.

What, now, are the details of structure and operation of this nucleic acid whereby it can perform this seeming miracle? That is where the brilliant conceptualization created by M. D. Watson and his associate F. H. C. Crick (*6, 7*) fits in. It would be presumptuous of me to attempt to review here, even if I were competent to do so—which I am not—how the double chain of nucleic-acid building blocks, or nucleotides, operates, on their hypothesis, to construct next to itself another chain identical in composition with its own, by a method that even incorporates in the new chain such mutations in the linear arrangement of the links as may have occurred in the original chain. Here we have the first real break-through on the chemical level in explaining the workings of the key process in all living matter. Although it is only 3 years since the first publication of this hypothesis, and 6 since Watson's days as a student at Indiana University, the concept has rapidly come to provide interpretations of findings in diverse biological fields, including those made in further work on the structure and mode of operation of the nucleoproteins themselves. It is being regarded ever less as a mere speculation and more as a solidly based theory, affording the critical connection between chemistry and biology.

Expansion with Variation

Let us now return to consider the effects, on the history of living matter, of this peculiar faculty of making copies of itself and its variations for which the Watson-Crick theory provides so fertile an interpretation. We see that living matter, unlike nonliving, is by reason of its doubling and redoubling always tending to expand, not like a gas that becomes more dilute and feebler in the process, but with increase of its mass and no relenting of its pressure outward and into diverse corners and crevices. In fact, the pressure of the living matter tends to increase with its expansion, since at the same time, by means of its mutations, it is trying out all sorts of new versions of itself and perpetuating

and sending furthest forward those that can expand the fastest and that can enter regions and situations that had acted as barriers to its earlier versions. Expansion with variation or rather, to state the matter more rigorously, the multiplication of mutant forms, this mode of procedure equals adaptation, since the ones that succeed in spreading are those which we call "better adapted" or "fitter." Let this continue for millions of millennia, piling refinement after refinement on one another, all chosen so as to favor still further expansion, into still less hospitable situations, and you finally arrive at our riotously rich living world of today—rich in its complications, capabilities, and diversity, yet as poor as ever, or poorer, in its standing room for the average individual.

In this present-day world, many comparatively primitive forms of life, such as bacteria, still remain with us, because they can multiply faster than more advanced forms in those numerous situations in which the materials for growth are ready at hand and in which the construction of elaborate equipment would only be a hindrance. The advanced forms are outfitted for overcoming serious obstacles, such as those encountered in carrying on their operations in a nonaquatic medium, or in deriving food from objects that offer resistance. In such situations, size is sometimes an advantage, as by giving strength or reducing dessication, yet increased size entails its own difficulties, such as those of supply and sanitation for the parts in the interior, and to meet the new requirements special devices must be installed through suitable mutations.

During this process of progression to forms that can accomplish ever more difficult tasks, the genes have been gaining increasingly refined and more far-reaching control over the materials around them, which they manipulate with increasing adroitness in the service of their own preservation and multiplication. Thus the hypothetical primordial, naked gene presumably could only accept, in a ready-made condition, parts like those of which it was itself composed, and fit them together into an image of itself. As groups of genes, step by step, adopted mutations that resulted in the establishment of protoplasm, however, these genes were having more and more effect in influencing the composition and behavior of material other than their own, making it into the protoplasm. This protoplasm was, in a sense, foreign matter that became enslaved to serve the end of gene preservation and increase. It was forced to act like an extension of the genes themselves, to influence outer circumstances to the genes' advantage.

In some lines of plants these genes, through their protoplasm, evolved means of controlling and making use of ever simpler, more abundant raw materials, such as nitrates, and sources of energy, notably sunlight. At the same time, in animals the increase of control beyond that exercised over their own protoplasm went largely in the direction of capturing food and avoiding being captured, but it also took the form of securing protection against the weather, bringing about mating, and so on. In the earlier stages of cellular forms, both plant and animal, a set of genes directly controlled the material of one cell only. But as larger and more intricate multicellular types evolved, the set of genes that the individual started life with, by making use of multiplications that produced sterile body cells, came to determine the composition and behavior of a much larger mass. The process of large-scale control went even further when the individuals of a colony, or of a whole population, came to cooperate. Along with this increase of the directly controlled protoplasm, there was very often an increase of the amount of indirect control, exerted through that protoplasm, on environmental materials and processes. The activities of food-getting; the construction of dens, dams, and traps; the action of roots in retaining water in the soil; and the attraction of insects by flowers to effect their pollination and of birds and mammals, by fruits, to disperse their seeds are some of the more obvious examples of organisms' activities in controlling the environment in their own interests—that is, in the interests of their genes. More broadly considered, their ecological influences in general fall into this category of processes.

In the animal kingdom (the key to the evolution of which is its dependence upon adroit movements for the capture of other organisms as food, in the absence of adequate chemosynthetic abilities) we find an increasing development of mobility that becomes ever more dexterous, versatile, and powerful, serving locomotion, defense, offense, feeding, mating, and, in general, the alteration of other objects in the interests of the individual or his group. The effectiveness of these movements underwent, as we know, enormous improvement with the increasing development of ever better integrated and more intricately acting coordinating systems, serviced by sense organs that gave more and more detailed and comprehensive signals representative of the outer world.

Advent of Intelligence

Although, at first, all or almost all the responses followed prearranged, inherited patterns which had evolved through the long process of natural

selection of mutations that had tested the advantages of this and that variation in pattern of response, after a while a mechanism arose and succeeded, which allowed variations in the patterns to become established in an individual when his repeated experiences had associated one action or another with an injurious or beneficial effect upon him. These words cover a multitude of deep unknowns relating to the genesis, the nature, and the operation of the process of forming "conditioned reflexes," or "association." Which of these two terms is used here is a relatively unimportant matter that depends upon whether we prefer to indicate the objective or subjective aspect of the process. This faculty of modifying actions in accordance with experience must depend on the ability to make and to retain neuronic connections between different patterns of neuronic activity that given experiences have aroused in conjunction with one another. The faculty has had its rise (though possibly its primary origin goes further back) in a number of radically different lines of animals that had developed nervous systems. Among these are the jointed-legged creatures such as insects, spiders, and crustacea; the higher mollusks, such as squids and octopuses; and the backboned animals. This multiple rise gives ground for inferring that it has evolved on other worlds as well as ours. As it becomes more developed, this forming of conditioned reflexes deserves to be called learning by experience and, finally, intelligence. However, there is no sharp line separating the different stages, and what we know as conceptual thought and imagination only represents its most advanced degree of development on our earth to date.

There is no use in attempting here a labored exposition of the advantages of learning by experience and intelligence, for they are obvious to every man. The advantages are of course the greater, the less stereotyped are the situations and the means of getting a living that are open to an animal. It would be of interest, had we the time, to trace the rise in learning ability that has gradually occurred in backboned animals, leading up to ourselves, in accordance with this principle, bearing in mind that when the advantage of a given type of modification is greater, the pressure of selection in fostering it becomes stronger and its evolution goes correspondingly further in a given time. At any rate, by the time of appearance of true mammals, some 70 million years ago, with their comparatively versatile life and elaborate care of the young, learning ability had attained a high premium. Judging by the rapidity of their increase in head size thereafter (although this measures only one of the many factors involved), learning ability did advance comparatively quickly in nearly all kinds of mammals in the years that passed after that time. The greatest strides in this respect were made in the group of monkeys and apes, no doubt in correlation with their more varied possibilities of living, moving, and behaving.

It is fashionable in some circles to refer slurringly to the inference that apes were ancestral to men, and to insinuate that Darwin's theory to this effect has been discredited and that it is more proper to say that men and apes, perhaps even men, apes, and monkeys, diverged long ago from a stem form that was more primitive than any of these. This is mere wishful thinking on the part of those who resent too vivid a visualization of their lowly origin and their present-day poor relations. For recent years have brought ever more concrete illustrations of the kinds of stages through which man has passed in his epic journey upward from the apes of Miocene times. Of course no present-day species of ape is ancestral to us, but if our Miocene ancestor of, say, 20 million years ago could be obtained alive today he would certainly be classified as an ape.

No Reason To Be Ashamed

We have no reason at all to be ashamed of this ancestry, for at the ape stage we were already far ahead of nearly all other animals in intelligence. In this connection we may recall the experience of Winthrop Kellogg and his wife, as told in their book, *The Ape and the Child* (*8*). In addition to their human infant, 1 to 2 years of age, this couple had for about a year a somewhat younger chimpanzee baby in their home, and they reared the two children together on as nearly an equalitarian basis as possible. Their human child (whom I knew) was a fine, bright little boy, and these remarks constitute no slur on him, for they would have been true in the case of other exemplary children. The point is that the tests and observations showed the two youngsters, in general, to be on very much the same level of ability, except that the human boy was better at understanding speech and was, of the two, the only one who tried to use speech himself at all, while on the other hand the chimpanzee youngster, besides being far more agile, and quicker at gaining such largely motor skills as using the toilet, proved somewhat better at solving novel problems in a rational way. Of course there is no doubt that if the experiment had gone on for several years longer the chimpanzee would finally have fallen behind the human in his insights. But at least the results obtained are enough to show what an advanced basis man already had to build on when he started to diverge from the ape.

There seem to have been two chief directions of advance in the genetic basis of mentality that were made by the human line in the course of its progress up from the ape. One direction was, of course, the increase in his ability to understand the workings of material objects and to utilize them to his advantage. For the freeing of his hands for manipulation—brought about by the adoption of an erect life on the ground—put a premium on his using tools and doing useful work on objects in general. The other direction, no doubt followed simultaneously, was his development of ever more effective and detailed powers of communication, and that meant, above all, speech. This required, for one thing, pronounced social feelings and activities (which some of the apes already possess to a fair degree), for speech is in the first place social in its function, serving to increase the effectiveness of cooperative behavior. But it also required the development, to a degree far beyond that possessed by any animal other than man, of an inherited predilection for symbolization, that is, for the mental association of isolates derived from experience with convenient but, in themselves, meaningless tags. This is a procedure that to a rational nonspeaking animal would appear quite irrational, frivolous, and useless. In addition, the growth of several subsidiary propensities was important: that of liking to use the voice to make all sorts of sounds, to play with them, to imitate them, and an improved ability to discriminate among them and remember them. These special propensities are at a sadly low level in the chimpanzee, except for his remarkable rhythmic drumming compositions, but some gibbons are natural vocalists.

Building of Culture

It is obvious to us that advances in both these directions—the technical and the linguistic—must have been advantageous to nascent man. However, the earlier steps must have been much less useful than the later ones, so that the genetic progress was probably very slow at first and, after a time, accelerated. During this same period a very remarkable new development was taking place that had not occurred to a major extent in any other terrestrial organism. That was the institution of cultural evolution. For, as techniques gradually improved with increased ability in technical thinking and doing, and as the ability to communicate likewise improved, then, since man is a family animal and a social animal, men and women came to pass along more of the fruits of their experiences, their techniques, their lessons for the conduct of life, and their thoughts, to their children and their fellows. Thus a great heritage outside that of the genes, a cultural heritage, gradually was built up. By its means one generation came, in a sense, to stand on the shoulders of the other, rank on rank, and to gain the experience of a Methuselah. If it had not been for this gathering together and accumulation of the mental and technical achievements of numberless people, through countless generations, into the heads of the individual persons and, later, the additional accumulation of specialized learnings and techniques in specialized categories of people, human beings would not have been able to rise so very much higher than the apes, after all, for their innate ability, aside from speech, is only moderately higher.

Although the abilities and proclivities needed for speaking had to undergo a great deal of genetic improvement in early times, the forms taken by speech itself were determined through lengthy processes of cultural evolution. Thus, the speech of any people constitutes one of the most important phases of their cultural development. Moreover, the further speech has developed, the more indispensable it has become not only in the transmission of thought between person and person but also within a person, so as to make possible for him far deeper levels of theoretical manipulation and understanding. Likewise, however, it readily leads to greater depths of obfuscation and of wholesale misconception. Thus it is a two-edged sword, one that needs strong, vigilant, critical, and suspicious masters. It seems likely that it has cut down great nations in their prime, but it would be a difficult task to document this point. At any rate, the half-truth contained in the old dictum of the Swiss-American zoologist Louis Agassiz, "Study nature, not books," needs to be taken very seriously.

Despite this and other dangers and serious setbacks, cultural evolution has, as we all know, succeeded in carrying men gradually forward until, about 10 or 12 millenia ago, some groups of men advanced to the level of growing their food, settling down, and using some of the small amount of resulting leisure for further improving their techniques in general. Not only agriculture but also towns were able to start up—that is, what we call civil life or civilization. As these methods spread and improved, the human population of the earth was enabled to multiply many fold, and the dominance of man advanced to a new level. Yet there are grounds for inferring that, genetically, the mental ability of men now is not significantly greater than it was in the Old Stone Age, represented by the Cro-Magnon paintings on the walls of Spanish caverns, some 25,000 years ago. We are all trained savages, trying to sublimate and to hide our urges.

Mistakes of Past and Present

Few of the advances of past civilizations have been really intelligent except in a short-sighted way. For men did not understand sufficiently the way things worked, either in material or social matters. In fact, even when a glimmering of understanding existed, few cared sufficiently to take the pains that were needed to safeguard the interests of their remote descendants. Thus, much land was brought under cultivation or under pasturage in such a way that it was gradually ruined. Forests were gradually cut down and left as stony deserts. People were conquered and brought under the rule of great empires, with admirable roads and a common body of laws, commerce, and finance, yet they were oppressed until they no longer had the will or the strength to resist the barbarian. Luxury went hand in hand with poverty, and progress faltered.

Only when, in the later Middle Ages, techniques and the practice of constructive reflection had recovered sufficiently to permit the rise of organized science were significant strides made in the understanding of how things work. Flowing out of that unprecedented understanding has come not merely the machine age but the age when, through knowledge of the ultrasmall and the ultralarge, the ultrafast and the ultraslow, we can increasingly control the composition and fabrication of materials, the transformation of energy in ways enormous and in ways deft and minutely directed, and even the natures of living organisms. This brings us up against potential achievements, as well as dangers, incomparably greater than those of the past.

As yet we are inclined to use these powers, which would have been miraculous to earlier generations, for purposes ridiculously more short-sighted than the vision of the thinkers whose discoveries and inventions made them possible. Some of these practices are having pernicious long-term effects that will plague and may even ruin future generations. Moreover, somewhat like adolescents who dash about in Cadillacs and try to just *not* hit head on, we "play chicken" at dropping hydrogen bombs on each other. Perhaps if a way were devised to make a rocket out of a whole planet and to ride it as it fizzed itself out, we would be squandering the planets themselves, just for fun. And if they could be whole galaxies, so much the better! The trouble is not that there is too much science but too much short-sighted application of it, too little dissemination of its deeper meanings, and too little appreciation of the need for proceeding by its method of free inquiry and unhampered discussion and criticism, private and public, in every sphere of existence and of thought.

Genetic Laisser Faire of Today

Let us take a few examples of this situation from the field of genetics. If people in general better appreciated their place in nature and the method by which they have become what they are, they might become concerned about a number of genetic trends of modern life. For one thing, they would come to realize that, as Wright (*9*) has pointed out, biological evolution in the past has usually proceeded by making use of the division of the population of a large area into numerous more or less isolated groups. These groups try different biological experiments, as it were, since mutations happen accidentally and different combinations of them become established in different places. Moreover, the locally differing conditions of living favor the multiplication of some types more in some places and others in other places. Some of the local types, or combinations of types, that thereby become established, could never have become so by a process of unprotected competition occurring throughout the large population as a whole because of their having been unsuitable, in the short run, for the average, over-all conditions. And yet later, these very types, through having become supplemented by certain other special features that arose within their small local groups, might afford exceptional advantages that would even be useful throughout the range of the species. Eventually, among the diverse peculiar types that have become established locally in this way, competition of group with neighbor group takes place, and the combinations that then happen to be fitter in relation to conditions in general spread more and more widely. Thus the population over its whole area gets to advance in unexpected ways that would not have been open to it if it had been just one huge, more or less evenly intermixing population.

We of the human species, however, are now rapidly becoming one of these huge, undivided populations. I am convinced that this process cannot be stopped and that it is salutary from a social point of view. But its retardation of biological evolution is an effect that must be reckoned with, and against which socially acceptable countermeasures need to be devised, involving some artificial influencing of selection.

Another genetic problem concerns itself with the long-term effect of our applications of science and technique in saving human lives and raising living standards. The effect today is to bring a security and ease of life never approached even by the aristocracy in past ages, thus freeing men for higher thoughts, crime stories on television, or more exciting auto rides. Most of the early deaths of

past times represented sheer waste, except that if everyone had lived, the pressure of population would soon have made people more miserable than ever. But a certain part of those deaths, perhaps a fifth or a quarter, represented the dying out of genetic combinations that were less suitable for leading normal human lives. In other words, they accomplished the elimination of harmful mutations. At the same time, some of the much more rarely arising, beneficial mutations managed to survive better, and so to be more abundantly represented in the next generation.

Thus the long-term influence of our modern advances in medicine and of all our artificial aids to life must gradually decrease the biological fitness of the population. This happens by the ever-increasing accumulation of all sorts of mutations that, under more severe conditions, would have been eliminated. Since new mutations keep occurring in every generation and are thereafter handed down unless some descendant dies of his disability, these mutations will tend to accumulate until the population is bearing as great a load of them as can be kept alive by its greatly enlarged cohorts of doctors, exercising their best medical skill and working overtime (*10*). Moreover, the more we add to the naturally occurring mutations by producing others, by means of atomic radiation or medical x-rays, the sooner this eventuality will materialize (*11*). At present we are woefully ignorant of the speed of the process. All this leads us to picture a future in which we all require vastly multiplied medications, hearing aids, glasses, crutches, dentures, and whatever other artificial members the great new medical science of the future will have devised. But then science itself may falter, for we will also have accumulated mutations that act to lower our IQ!

All this doubtless seems too ludicrous and too paradoxical to be believed. It is being here presented not as a result that is likely to happen but as one that would happen if we kept on living and acting as we now do. However, I have enough confidence in the ultimate ability of human beings to see things straight, and in their sense of responsibility, to believe that once they are aware of the facts of genetics and evolution they will be willing to repattern their behavior in conformity with the long-term view. This does not mean that they will try to go "back to nature" and become more ruthless, so as to let their weaker fellows die. Quite the contrary, they will extend their utmost cooperation to everyone. But their sense of responsibility will be sufficiently developed to lead those who are more burdened with genetic defects to avoid reproduction voluntarily. At the same time, those genetically more fortunate will regard it as an obligation to have a larger family. And society, instead of hindering them by allowing such practices as the exclusion of families with children from favored dwelling places, will value their efforts in behalf of the coming generation and will extend abundant aid to them in this work.

Control of Our Destiny

The possibilities in these directions have here been touched upon only with the stroke of a feather: in fact, a very soft feather! For new knowledge brings new techniques, and new techniques bring new knowledge. It would be foolish to attempt here to delimit the creativity of the biological knowledge and techniques of the future in opening up the way to faster and sounder human evolution. Neither can we here give due attention to the all-important subject of what, in the light of our knowledge of man's position in nature, he should regard as most desirable in himself. Along these lines, sages of the past have given us some truths that in one form or another will always be recognized, such as the superlative worth of brotherly love, of moral courage, of wisdom. These value judgments can be shown to be in harmony with the lessons taught by a study of biological evolution. But that study can help us to make these lessons more concrete and to extend and refine upon them, for whatever we do in altering nature must be made in full awareness of nature's own reactions to and on ourselves.

There are some voices that say it is wrong to interfere with nature's ways. These voices are untrue to the facts of life and, more especially, of human life. From the start it was the genius of the gene to manipulate other materials in the service of its own expansion and thus to interfere with nature outside itself. As it evolved it brought ever more material from its environs into subjection to it, and in consequence it kept securing its position and expanding. When, through higher organisms, it had reached the level of conscious purposes, these were directed to such mastery over the environment as would serve its needs. Man has simply succeeded in carrying the process inordinately further than living things have ever carried it before and, recently, in becoming conscious of it as a whole as well as in details. As he becomes ever more far-seeing man will also become farther-striding. But to safeguard his victories and to attain increasing inner harmony and richness, he will eventually find ways of reaching down into himself, to do ever better that which natural evolution fell short of when it molded him to reign supreme among the organisms of the earth.

No doubt to many people this whole viewpoint seems utterly visionary and not to be taken seriously. That is because the most fantastically impossible seeming things in existence are the products of biological evolution, the creations of the gene. Yet here they are. We biologists in our day-to-day experiences in the laboratory encounter these products, ranging from viruses and microbes on up to flowering plants, flies, and mammals. Moreover, we come to deal pretty directly with those elusive yet abundantly demonstrable processes that, working over vast periods, have converted one type into the other and that have eventually transformed microbes into men. We know we can influence these processes and we have made good starts in the alteration—we cannot yet say improvement—of such organisms as fruit flies, while poultry and other domestic forms have been modified in some ways that are highly advantageous, not for themselves but for us.

Man is a prober and a meddler, and in this, so long as he holds true to his own gifts, he will not stop. Undoubtedly what he will know and be able to do along biological lines only a few generations hence would seem like a science-fiction dream to most of us today, just as I can remember when, in my childhood days, people scoffed at the idea of man's ever flying in the air as quite absurd and impractical. Since I have learned this lesson, I regard it as more prudent not to attempt to set forth here any remoter thoughts about what there is in store for man in the future except to say that I am convinced that, unless he shortsightedly destroys himself, as by means of radiation, he will remake himself. He has, of course, since primitive times, continued to remake himself culturally, but he can and I think will do so genetically as well, and the combination is far more effective than either course alone. We should not be afraid of this. For, as we increase in understanding and in achieving more actively harmonious relations within ourselves and with one another—the aims which will surely be recognized as paramount—we will become ever better capable of guiding our progress in the future.

We transitional creatures must not shrink from our destiny or fear it. By working in functional alliance with our genes, we may attain to modes of thought and living that today would seem inconceivably god-like. In this expression the word *thought* has advisedly been set before *living*. For thought is the distinctive and central mode of existence of man, the new mode of expression of the genes, and in the beings who succeed us, if we ourselves win out, creative thought will ever more truly come into its own (*12*).

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Canalization of the Moselle

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A GENERALLY unnoticed item in the 1956 agreements signed between France and Germany concerning the Saar provides for canalization of the lower Moselle River. Improvement of the river for navigation is a relatively simple undertaking, involving no unusual technical problems. A series of dams, built in an assembly-line fashion on solid rock foundations, is proposed. Furthermore, the value of a navigable Moselle to the Western European Community as a whole, at least in an economic sense, can easily be shown.

Nevertheless, agreement on canalization has been long delayed, for the region concerned is divided among three political units, each of which has vigorously sought to protect its own interests. That western Europe as a whole will benefit does not mean that the parts concerned will benefit equally. Now, however, political and economic difficulties seem to be settled, and canalization is to begin. In this respect, it seems appropriate to review the features of the Moselle Valley, the plans for the canal, and the local industrial and transportation resources, with an estimate of the effect of canalization upon them.

Historical Perspective

The lower Moselle River represents the European counterpart of the North American St. Lawrence. Both are historic passageways, yet they are unusable by modern shipping, because of the shallowness or swiftness of their waters. Each severs the continuity of important waterways above and below, the lower St. Lawrence and Great Lakes on the one hand, the Rhine-North Sea and the upper Moselle-French canal system on the other. Both are astride the direct route between major areas of development. Both represent undeniable economic advantages to large regions as a whole, yet they provoke a clash of individual interests. Recent events have brought about acceptance of the St. Lawrence Seaway; canalization of the Moselle, almost accomplished in World War II, now seems probable in the near future.

Once, the Moselle served as an important Roman roadway between the Rhone and the Rhine, a roadway marked by the ancient cities of Trier and Koblenz. Today the Moselle is the single German river of note that is virtually untouched by modern development. Still crossed mainly by ferries, rather than by bridges, the lower Moselle retains a rural charm and beauty of landscape much the same as that praised by Roman poets 2000 years ago.

Modern use of the Moselle for navigation is restricted to the central and upper portions in Lorraine. Today, the river is canalized from Thionville to Epinal, where the Canal of the East connects with the Saône-Rhone corridor. At Nancy, on the tributary Meurthe, connections are also made with the Rhine-Marne Canal, the route to Strasbourg and the Rhine being especially significant. Lack of navigational use of the lower Moselle is a result of a complex set of circumstances, partly the physical nature of the valley, and, to a greater extent, the political and economic rivalry among Germany, France, and Luxembourg. Development of the Schuman Plan, NATO, and other post-World War II arrangements have made possible the removal of economic and political barriers, so that interest in overcoming the physical problems has been greatly stimulated.

The present impetus for canalization has come from several sources, the chief being the Government of France. In the act of 10 April 1952, authorizing the president of the French Republic to ratify the treaty instituting a European Community of Coal and Steel (Schuman Plan), article two directed the French Government to "enter into negotiations with the governments concerned, before establishing the common market, in order to achieve without delay the canalization of the Moselle between Thionville and Coblenz." In March 1953, the French Government opened the negotiations provided by the act. At the same time, boards of German, French, and Luxembourg experts drew up a joint outline concerning technical problems involved, including the pertinent economic aspects (*1*, p. 8). The chambers of com-

merce of Metz, Luxembourg, Trier, and Koblenz also formed a Moselle River Association, which advocated establishment of an international organization to carry out the canalization.

However, the decision regarding canalization could be made only by Germany and Luxembourg, the two countries through which the lower Moselle actually flows. On 27 October 1956, Germany agreed, in a signed treaty, to cooperate with France in constructing and financing the project in return for political and economic sovereignty in the Saar. In a separate treaty with Luxembourg, the French agreed to build certain port installations in Luxembourg and help electrify the Luxembourg railway system in exchange for permission to proceed with canalization in that portion of the Moselle.

Moselle Valley

Although it originates in the geologic Paris Basin, the Moselle does not flow toward Paris but turns toward the Rhine, crossing the Rhine-Slate Massif in order to do so. Near Thionville and Metz, the river flows in a wide valley at the foot

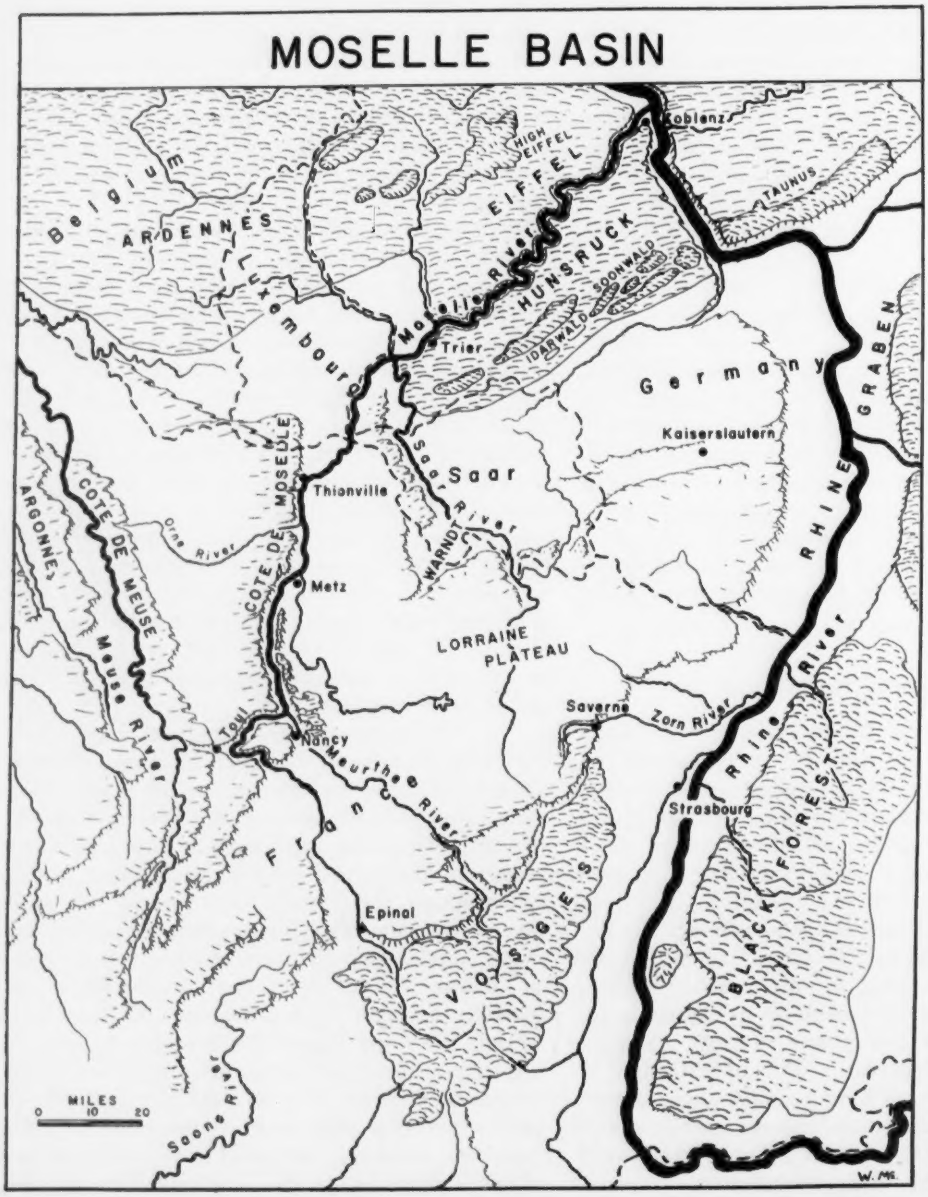

Fig. 1. The Moselle Basin appears to have a natural orientation toward the Rhine. Canalization between Trier and Koblenz would simplify logical economic cooperation between Lorraine and the Ruhr.

Fig. 2 (left). Terraced vineyards line the gorge wall of the Moselle a short distance upstream from Koblenz. The swift river fills nearly all the valley floor. Fig. 3 (right). The Koblenz dam represents the first step in canalization of the Moselle. A hydroelectric plant stands on the southern end, navigation locks being located near the north bank.

of a pronounced cuesta, the Côte de Moselle (Fig. 1). The upper course, working in sedimentary formations, tends, for the most part, to have a wide and open valley. As a result, canalization and improvement for navigation were not difficult.

Upon entering the ancient hard rocks of the Rhine Massif, the Moselle displays a markedly different pattern. The geologic uplift of the massif to its present elevation took place in two distinct stages. After the first stage, the Moselle formed a wide valley, with the river meandering in a sweeping serpentine fashion. The final uplift caused the river to incise its meandering course in a deep narrow gorge, leaving its former valley floor as a noticeable terrace above (*2*). At the bottom of the restricting gorge, the Moselle swings around its curves in vigorous fashion, too shallow and rapid for commercial navigation.

Sunny sides of the gorge are covered with elaborately terraced vineyards; the shady areas, with orchards of apples and cherries (Fig. 2). Crumbling castles survey the tranquil beauty of the valley from strategic heights above, looking down upon peaceful villages strung out along the narrow valley floor. Ancient alluvium of the high terrace supports a flourishing array of field crops, but forest quickly shuts in the horizon of the plateau itself.

Plans for Canalization

Various plans for canalizing the lower Moselle have been proposed by German governments since the start of the 20th century, but after 1918 canalizing of German rivers was restricted to purely German waterways, such as the Main and Neckar. By 1938, however, the German Minister of Transportation formulated plans for a new Moselle project from Koblenz to the border. With the addition of Lorraine and Luxembourg to German economic territory after June 1940, the project was extended to reach Thionville. A large dam was to be built at Koblenz, with channel deepening by dredging up to Trier. Upstream from Trier, a series of dams was to be constructed. Although work on the Koblenz dam was interrupted in 1944, the structure has since been completed (Fig. 3).

In order to produce electricity and to insure year-round navigation depths for big Rhine barges of 1500 tons, German, French, and Luxembourg engineers have decided to abandon dredging and to canalize the river completely with 13 dams. The project is divided into two main sections, Thionville to Trier, and Trier to Koblenz, the dividing line being set by junctions of the Saar and Sure rivers. The Thionville-Trier section will have limited production of electricity, because of slow velocity of the stream and low height of dams, and is further divided into subsections by the French-Saar-Luxembourg border at Apach. Thus, nine of the ten electric generating plants to be constructed will be in German territory between Trier and Koblenz, and the tenth will be on the German-Luxembourg border. The dams will provide a minimum channel depth of 8.2 feet and minimum width of 164 feet, which is sufficient for 1500-ton barges. Of the total length, 19 miles will be in France, 28 miles in Luxembourg, and 122 miles in Germany. No unusual technical problems are involved; hence, dam construction should be very routine. The whole project could be completed in 4 or 5 years. Since the Iron Mines Canal upstream from Thionville can handle small barges only, it

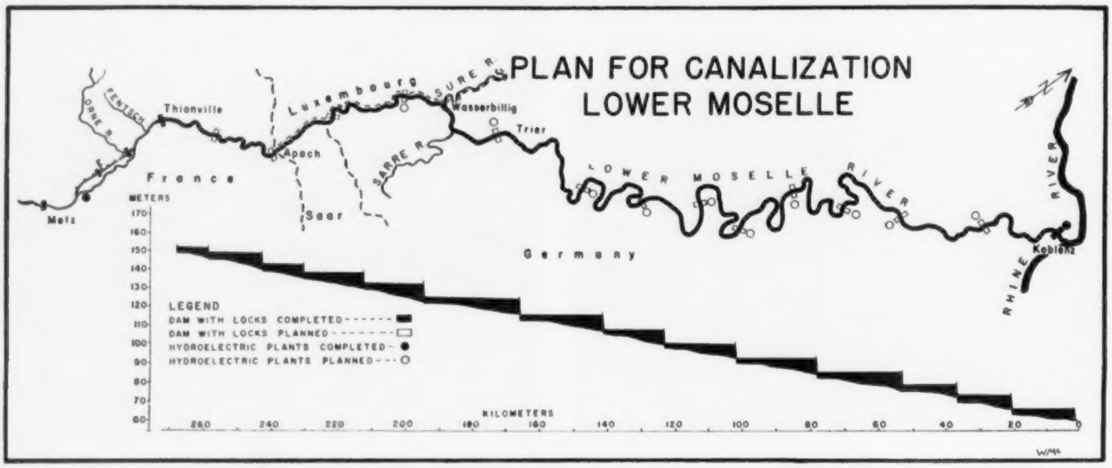

Fig. 4. The plan for canalization is a joint preparation by German, French, and Luxembourg engineers. With additional work above Thionville, 1500-ton barges will be able to reach Metz. [From Consortium pour l'Aménagement de la Moselle, *La Canalisation de la Moselle*]

must be enlarged to permit Rhine barges to penetrate beyond Thionville. In addition, a big Luxembourg port is to be constructed at Wasserbillig where the Sure River joins the Moselle (*1*) (Fig. 4).

In 1952, estimates for the work made by the Wasserstrassendirektion of Mainz and Service de la Navigation of Nancy set the cost for dredgings, locks, dams, ports, indemnities, and water power plants at $106,700,000, not including running interest. This figure is about one-third of the cost of the Rhine-Main Canal as far as the Danube, with electric power plants excluded. Estimates in 1956 now approximate $130 million, about half of which is designated for construction of hydroelectric facilities in Germany.

Responsibility for building and financing the hydroelectric installations (all in Germany) has been assigned to the private German RWE power company. To finance and construct the canal, a joint European company is to be formed, with work beginning in 1957 (*3*). The possibility of loans from Swiss and Netherlands banks is being investigated, and the World Bank is reported to have indicated a willingness to participate in the financing. The United States Government has no direct connection with the plans to canalize the river, nor is official consideration being given to the idea of financial help for the project by the United States (*4*).

Economic Motivation

Economic motivation for canalization is rooted in the strategic position of the Moselle in relation to the two most highly developed industrial basins of northwestern Europe, the Saar-Lorraine–Luxembourg Basin being second only to the great concentration of industry in the Ruhr. Rhine River traffic in 1952 amounted to 68 million tons, in contrast to 65 million tons for all French maritime ports during the same year. A major portion of this traffic involves shipments to and from the Ruhr, for the Ruhr port of Duisburg had a Rhine traffic of 15.8 million tons. In addition, the Rhine-Herne Canal, joining the Rhine at Duisburg, had a Rhine traffic of 13 million tons. The combined traffic exceeded that for the same year at Marseille (18.3 million) or LeHavre (16 million) (*1*, p. 13). These figures reflect the significance of water shipping for such bulky materials as coal, iron, steel, and related products. Similar raw materials and finished products are typical of that territory made up of the Saar, northern Lorraine, and southern Luxembourg, all of which are within reach of the Moselle (Fig. 5).

Waterway Cargo Materials

The famed Minette iron deposits of Lorraine outcrop along the exposed flank of the eastward-facing Côte de Moselle, so that the cuesta forms a sharp eastern boundary to the ore fields (Fig. 6). Since the geologic formations dip westward, mine shafts penetrate more and more deeply to the rear of the escarpment. As a result, mining is very concentrated in tributary valleys incised into the cuesta formation. In the north, Longwy in the Chiers Valley, a tributary of the Meuse, is an example. However, tributaries of the Moselle north of Metz, such as the Orne and Fentsch, form the

greatest concentrations of mining activity. The mines have attracted blast furnaces, steel mills, rolling mills, and all the accessories of iron and steel industries, so that the narrow deep valleys form continuous industrial developments which spill out into the Moselle Valley in the vicinity of Thionville. Farther south, where the Moselle angles across the cuesta, iron deposits extend on both sides of the river, forming the basis for another mining and heavy industry center around Nancy. From Nancy to Luxembourg, the iron deposits cover possibly 300,000 acres, containing an estimated reserve of 5 billion (10^9) tons. More than 80 percent of the smelted iron and more than 70 percent of the steel produced in France come from Lorraine (*5*).

Directly east of Metz, the Lorraine-Saar border area consists of an anticlinal fold, the eroded center of which now forms the Warndt Basin. Here are exposed the coal deposits which are the basis for the economic wealth of the Saar. The deposits extend into France, furnishing an important coal-mining district around such cities as Forbach, Creutzwald, and St. Avold. Despite the disruption of frequent wars and changes in political sovereignty, the Warndt Basin plays an important part in the heavy industry development of Lorraine.

Production figures for coal, steel, and iron ore in

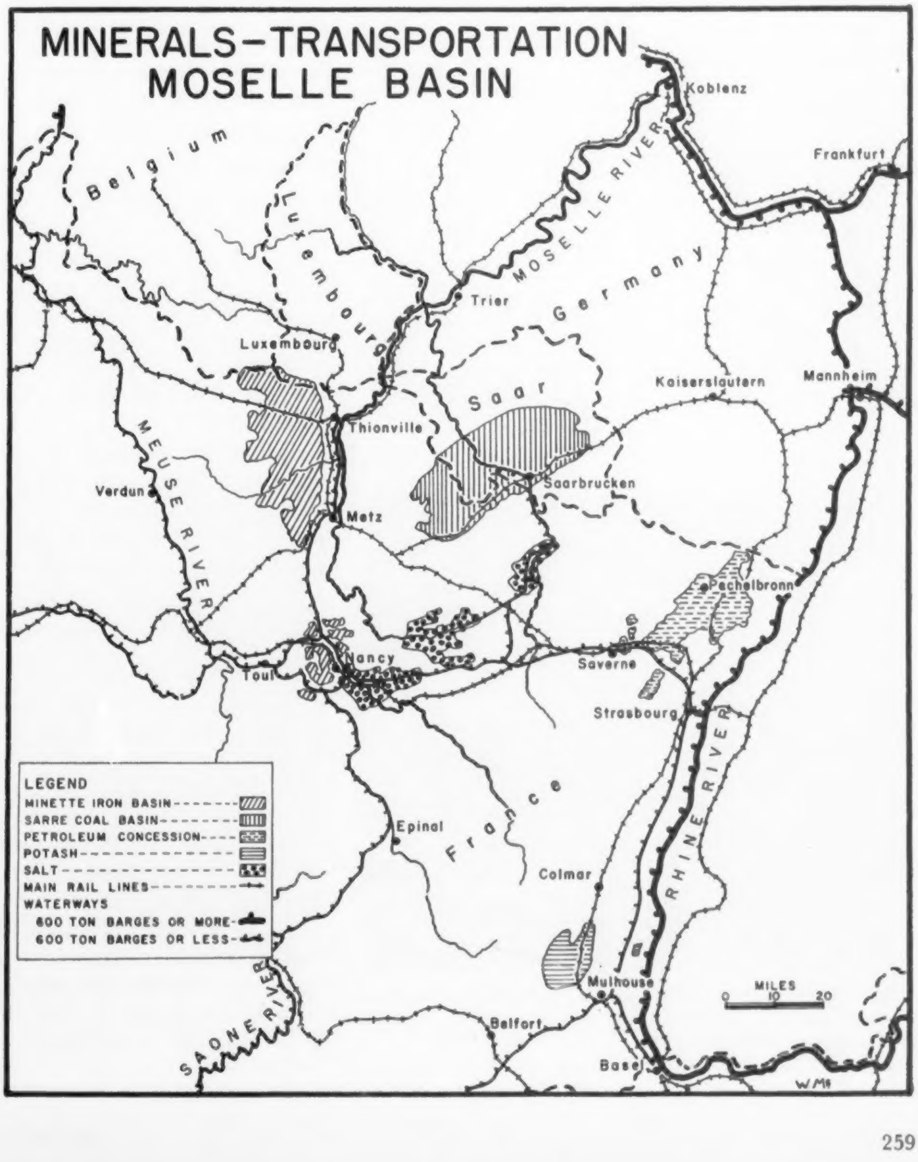

Fig. 5. Bulky raw materials characterize the Moselle Basin. Water transportation lends itself to both regional and international movements.

Table 1. Coal, steel, and iron ore production (in metric tons) for the Saar-Lorraine-Luxembourg area (*1*).

Country	Coal	Steel	Iron ore
Saar	16,235,000	2,823,000	
Lorraine	12,210,000	7,124,000	37,745,000
Luxembourg		3,001,000	7,245,000
All France	53,360,000	10,870,000	40,710,000
West Germany	123,280,000	15,810,000	15,400,000
European Community	238,880,000	41,810,000	64,340,000

1952 emphasize the significance of the Saar-Lorraine-Luxembourg area as a major producer for western Europe (Table 1). In particular, the contribution in regard to iron ore is especially obvious. In addition, limestone and sandstone, sand and gravel, salt deposits east and southeast of Nancy, potash from southern Alsace, and possible oil resources north of the Saverne gap around Pechelbronn add to the list of bulky raw materials available in the general vicinity of the Moselle system of waterways.

Of still further consequence is the relation of Saar-Lorraine-Luxembourg raw materials to those of Belgium and Germany. Although Lorraine supplies iron ore to all major industrial areas of western Europe, Lorraine in turn must import coal, particularly coking coal from the Ruhr. The bulk of this necessary exchange is carried out at present primarily by rail. High railway rates present a difficult problem to the mining and steel industries.

Fig. 6. The Côte de Moselle bars the western horizon near Thionville. This cuesta contains the famed Minette iron deposits of Lorraine.

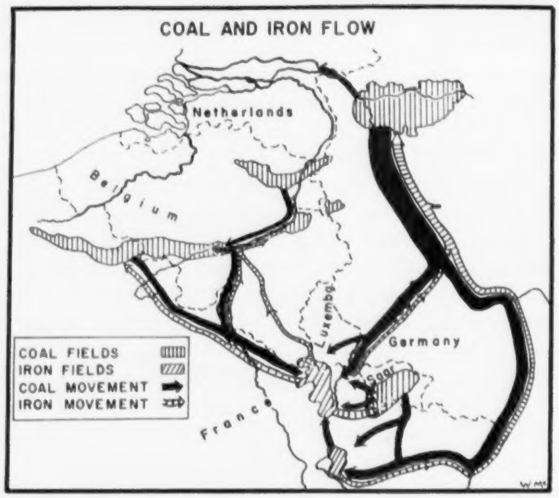

Fig. 7. Flow of coal and iron illustrates strategic location of lower Moselle. Width of arrows is generalized to indicate relative strength of movement. [Adapted from J. Chardonnet, *Atlas de l'Europe Occidentale*]

Inexpensive water transportation is handicapped by the fact that the Saar and Lorraine are connected only with the general network of French canals and with the southern portion of the Rhine only. In order to avoid expensive rail transportation, considerable Ruhr coal and many other products are actually shipped as far as Thionville by a roundabout water route (Fig. 7) through Strasbourg, Nancy, and Metz, a detour of more than 200 miles!

A large part of the steel produced in the Lorraine region is exported. Since this means a journey of some 190 miles to the nearest North Sea port, the cost of transportation for processed materials also becomes a major interest.

Available Transportation

Since the greater part of present exchange of heavy materials is by rail, several railroad centers of importance have developed on the Moselle. Metz, on the main route between Paris and the Rhine Valley, is the focal point for a line through the Saverne gap to Strasbourg and for another line angling to the northeast through the Saar and Kaiserslautern to Mannheim and Frankfurt. Thionville, despite its distance from the border, is in a sense a French port of entry, especially for lines to Belgium and the Netherlands as well as those toward the Rhine through Trier and Koblenz. Much of the traffic to and from Thionville thus passes through Luxembourg, giving that little

country a very important and economically significant position. Thionville is also connected by rail with the coal fields and industrial areas of northern France as well as with channel ports, such as Dunkerque. Nancy, too, represents a rail crossroads, the center of east-west and north-south routes.

The present canal system linked with the Moselle is, in general, quite old and in a poor state of repair. Canals contain many locks and are accessible to smaller barges only (Fig. 8). An exception is the Moselle Iron Mines Canal, constructed in 1932 to connect Metz and Thionville (Fig. 9).

Because the lower Moselle is not navigable, the Metz-Thionville canal serves primarily as a means of internal navigation in the Thionville area, being little more than a junction between industrial establishments of that particular district. The older canals in the south, however, have a very important role in the industrial development around Nancy. Especially is this true for the importing of coal, which comes from several directions. From Belgium, northern France, and Calais, coal is shipped to the Nancy area by the Ardennes Canal and Canal of the East; from the Ruhr, coal comes by way of Strasbourg; and from the Saar, shipments travel by way of the Canal of the Coal Mines. The Rhine-Marne Canal serves as the ultimate collector of all these routes. In addition, the salt industry east of Nancy, the iron mines, steel mills, chemical factories, quarries, and similar producers of bulky products make use of the existing canal network (*6*).

Advantages of Canalization

Canalization of the lower Moselle will obviously decrease the transportation costs involved in exchange of coal and iron ore between Lorraine and the Ruhr as well as the cost of exporting finished materials through Rotterdam. In 1952, transportation costs for a ton of Ruhr coal to Lorraine, 360 kilometers, was about 2400 francs, or about 35 percent of the final selling price. At the same time, a ton of Ruhr coal could be shipped to Rotterdam, 250 kilometers, for 250 francs. Transportation costs equaled about 60 percent of the price for iron ore, and 20 to 25 percent for flat rolled steel. Estimates of the various components of transportation costs, such as freight rates, tariffs, taxes, loading and unloading, cartage, and similar items have been worked out by the various organizations interested in canalization of the Moselle. Table 2 illustrates the theoretical advantages of water shipping between specific sites in 1952.

Based on an assumed 20-percent increase in annual production of Franco-Saar steel, ultimate yearly traffic on the lower Moselle is conservatively estimated to include the tonnages indicated in Table 3. In view of the volume of traffic on the Main River (7 million tons annually) and the Neckar (4 million tons annually), these figures do not seem to be too high. Formerly, the Ruhr took 3 million tons of ore from Lorraine, so the 1-million-ton estimate is very conservative, especially in view of the total importation of 10 million tons of iron ore into the Ruhr in 1952.

Fig. 8 (left). Locks in Moselle Iron Mines Canal, Metz, illustrate the limitation of barge size in French canals. Big Rhine barges cannot penetrate here. Fig. 9 (right). The Moselle Iron Mines Canal, paralleling the Moselle River near Thionville, is one of the few modern (1932) canals in the French system. It, too, should be enlarged.

Table 2. Shipping costs per metric ton (*1*).

	Railroad	Waterway	Savings
Coking coal from Ruhr to Rombas (near Thionville)	\$6.95	\$3.75	\$3.19; 46%
Iron ore from Lorraine Mine Angevillers to Ruhr factory, Gelsenkirchen	\$3.24	\$1.61	\$1.63; 50%
Flat rolled steel from Rombas to Rotterdam or Antwerp	\$6.31	\$2.18	\$4.13; 65%

Although the transportation aspect of canalization is to the special advantage of France, Germany stands to gain primarily in added sources of hydroelectricity. The Moselle crosses the Rhine-Palatinate State, which had to import 73 percent of its power in 1951. Including the Koblenz plant already in existence, annual hydroelectric production should reach 810 million kilowatt hours.

Transportation costs of Lorraine iron ore to the Ruhr would obviously be much lower. Furthermore, certain local developments along the Moselle Valley, such as flood control, regional development through use of electricity and lower transportation costs, and possible exploitation of local mineral resources could ensue. Trier, strategically located on a deep water route between the Ruhr and Lorraine, and with improved access to important Rhine cities and North Sea ports, should enjoy outstanding opportunities for development of industry and trade (*7*).

Benefits should also accrue to the entire European Coal and Steel Community through more efficient development of regional resources. The additional Rhine traffic will be of importance, not only to Germany, but also to the Netherlands' port cities of Rotterdam and Amsterdam. Direct waterway importation of high-grade iron ore from new mines being developed in North Africa and of United States coal will be possible. It is expected that Lorraine steel mills will import at least 500,000 tons of coking coal per year from the United States (*3*).

Opposition to Canalization

In terms of the "Western European Community," economic arguments for canalization seem very reasonable. Nevertheless, European unity is a long way from fact, so that special interests have managed to delay the program. Only when the entire region was under control of one country (Germany) was any real progress made toward the canalization. Rivalry among Germany, France, and Luxembourg has handicapped over-all development of the river.

Since France is more dependent on Ruhr coke than the Ruhr is on Lorraine iron, the present advantage in competitive position of Ruhr steel producers would be affected by a heavy reduction in cost of coke to French mills. Iron production in Germany has a big advantage in cost price, ranging from 7 to 39 percent. This advantage stems from differences existing between prices of coal and coke according to site and nature of coal mine centers, varying degree of concentration of iron works, and differences between state or customs duties (*8*).

Because of the high cost of rail shipment, France imports coke rather than coking coal from the Ruhr. With inexpensive water transportation, the coal could be shipped to Lorraine to be coked, thus depriving the Ruhr of valuable by-products from the coking process. Competition with United States coal may be involved, also. Industrial leaders from the Ruhr have argued persistently that the project will benefit Lorraine more than any other district, thus removing canalization from the category of an "European project," so that it should not be considered in terms of the "Western European Community."

Other segments of the French iron and steel industry also fear that their competitive position will be worsened, and French railroads do not wish to

Table 3. Estimated ultimate Moselle traffic (*1*).

Upstream	Traffic (metric tons)	Downstream	Traffic (metric tons)
Coke for Lorraine	2,560,000	Ore for Ruhr	1,000,000
Coking coal	1,930,000	Saar-Lorraine steel:	
		Products to North Sea ports	1,900,000
Ore for Lorraine	500,000	Half-finished steel products	100,000
Other items (dolomite, construction materials, etc.)	350,000	By-products	550,000
Transit traffic	100,000	Transit traffic	300,000
Total	5,440,000	Total	3,850,000

lose their present advantageous position. French channel ports foresee themselves bypassed in favor of Rotterdam. The Saar and Strasbourg, the big French Rhine port, actively opposed the plan for fear of losing business to the Ruhr and the Moselle. Luxembourg was quick to object to any attempt to deliver Ruhr coal to France without using the short and high-cost Luxembourg railway system. Belgium preferred a canal from Liége to Thionville via the Meuse River to favor her ports, a possible but much more expensive alternative.

In view of the traditional hostility between France and Germany and the bitter opposition from elements within all countries involved, the signing of the treaties concerning canalization of the Moselle represents a tangible gain for European cooperation.

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ASSOCIATION AFFAIRS

Tatum Named to Editorial Board

It is a pleasure to announce that Edward L. Tatum was appointed to the editorial board of *Science* and the *Scientific Monthly* on 1 Apr. Tatum, now 47 years old, took his A.B. degree in chemistry, his master's degree in microbiology, and his Ph.D. degree in biochemistry at the University of Wisconsin, thus getting a strong background in several sciences.

Following a year as research assistant in biochemistry at Wisconsin (1934–35) and a year as a fellow of the General Education Board at Utrecht (1936–37), Tatum joined the Stanford University biology department, where he was a research associate (1937–41) and an assistant professor (1942–45). After having served on the Yale University faculty, first as associate professor of botany (1945–46) and then as professor of microbiology (1946–48), he returned to Stanford as professor of biology. He held this post until he became a member of the Rockefeller Institute for Medical Research in January of this year.

Edward L. Tatum

Tatum has served many national scientific bodies, and at present, in addition to being on the National Science Board, he is a member of the Committee on Virus Research and Epidemiology, National Foundation for Infantile Paralysis; the Biology Council, National Research Council; Biology Panel, National Science Foundation; and the Research Advisory Council, American Cancer Society. His honors include the American Chemical Society's Remsen award, selection as the Herter lecturer at New York University, and membership in the National Academy of Sciences.

His special interests have been the nutrition and metabolism of insects and microorganisms and the biochemistry and genetics of microorganisms. Some of his most significant research results are as follows: identification of thiamine as a growth factor for proprionic acid bacteria; isolation and identification of kynurenine as an eye-color hormone in *Drosophila* (with G. W. Beadle); discovery of biochemical mutants in *Drosophila* (with G. W. Beadle); biochemical mutations in bacteria; gene recombinations in *Escherichia coli* (with J. S. Lederberg); biosynthesis of tryptophan (with D. M. Bonner).

Tatum's wide-ranging scientific interests, outstanding research accomplishments, and diverse academic experience make him notably well qualified to serve as a member of the editorial board of *Science* and the *Scientific Monthly*. In addition, his experience since 1948 as a member of the editorial board of the *Journal of Biological Chemistry* and as assistant managing editor of the *Annual Reviews* (1948–53) should serve him well in his new post. We welcome Tatum as a distinguished new member of our editorial board.—G. DuS.

AAAS Socio-Psychological Prize

Through the generosity of an anonymous donor, the AAAS offers an annual prize of $1000 for a meritorious essay in socio-psychological inquiry. Previous winners of this prize and the titles of their essays have been: Arnold M. Rose, "A theory of social organization and disorganization"; Yehudi A. Cohen, "Food and its vicissitudes: a cross-cultural study of sharing and nonsharing in sixty folk societies"; and Herbert C. Kelman, "Compliance, identification, and internalization: a theoretical and experimental approach to the study of social influence."

The conditions of competition for the prize to be awarded at the 1957 annual meeting, Indianapolis, 26–31 Dec., are as follows.

1) The contribution should further the comprehension of the psychological-social-cultural behavior of human beings—the relationships of these hyphenated words being an essential part of the inquiry. Whether the contributor considers himself to be an anthropologist, a psychologist, a sociologist, or a member of some other group is unimportant as long as his essay deals with basic observation and construction in the area variously known as

social process, group behavior, or interpersonal behavior. For ease of reference in the rest of this statement, this general area will be called "social behavior."

2) The prize is offered to encourage studies and analyses of social behavior based on explicitly stated assumptions or postulates, which lead to testable conclusions or deductions. In other words, it is a prize intended to encourage in social inquiry the development and application of dependable methodology analogous to the methods that have proved so fruitful in the natural sciences. This is not to state that the methods of any of the natural sciences are to be transferred without change to the study of social behavior, but rather that the development of a science of social behavior is fostered through observation guided by explicit postulates, which in turn are firmly grounded on prior observations. It may be taken for granted that such postulates will include a spatial-temporal framework for the inquiry. It may properly be added that the essay should foster liberation from philosophic-academic conventions and from dogmatic boundaries between different disciplines.

3) Hitherto unpublished manuscripts are eligible, as are manuscripts that have been published since 1 Jan. 1956. Entries may be of any length, but each should present a completed analysis of a problem, the relevant data, and an interpretation of the data in terms of the postulates with which the study began. Preference will be given to manuscripts not over 50,000 words in length. Entries may be submitted by the author himself or by another person on his behalf.

4) Entries will be judged by a committee of three persons considered well qualified to judge material in this field. The judges will be selected by a management committee consisting of the chairman and the secretary of Section K and the executive officer of AAAS. The committee of judges reserves the right to withhold the prize if no worthy essay is submitted.

5) Entries should be sent to Dael Wolfle, Executive Officer, American Association for the Advancement of Science, 1515 Massachusetts Avenue, NW, Washington 5, D.C. Entries should be submitted in quadruplicate. Each entry should be accompanied by four copies of an abstract not to exceed 1200 words in length. The name of the author should not appear anywhere on the entry itself but should be enclosed on a separate sheet of paper which also gives the author's address and the title of his essay. Entrants who wish to have their manuscripts returned should include a note to that effect and the necessary postage. To be eligible for consideration for the prize that will be awarded at the 1957 annual meeting of the Association, entries must be received *not later than 1 Sept. 1957.*

BOOK REVIEWS

Freshwater Fishery Biology. Karl F. Lagler. Brown, Dubuque, Iowa, ed. 2, 1956. 421 pp. Illus. $6.75.

The second edition of Karl Lagler's guide to fishery biology is significantly enlarged and more comprehensive than the 1952 edition. New techniques, such as the use of free diving and television equipment in fishery research, are discussed. Each of the 25 chapters has been revised to include the latest research findings, and the lists of references for each chapter include several new titles. These bibliographies, by subjects, would in themselves justify a place for *Freshwater Fishery Biology* on the bookshelves or, even better, desks of fishery biologists.

The book outlines most of the techniques used in fishery biology: age and growth; length-weight; food habits; tagging; population estimation; fish culture; lake, pond, and stream surveys; and habitat improvement. Sample forms for field and laboratory records are given, and several exercises are outlined for use in laboratory periods of a college course. More emphasis might be placed on sampling problems and the statistical analysis of the results, but the present edition moves in this direction more than did the earlier edition.

A very helpful feature of the book is the concise organization of large amounts of data for convenient reference. Some of the more useful tabulations include: outline for life-history study of a fish, comparison of various systems of classification, bibliography by states and regions, von Bayer's table for estimating number of fish eggs, pathologic conditions, descriptive summary of fish parasites, hazards of municipal and industrial effluents, basic fish culture practices for representative fishes, map symbols, chemicals for water analysis, stocking rates for small ponds, and economic and taxonomic classification of common and representative freshwater fishes. Illustrations of anatomy, embryologic

stages, and fish scales, with annuli marked, provide data for ready reference.

The largest single addition in the second edition is a 40-page survey of the freshwater fishes of North America. This section will be of considerable value in those curriculums where the book is used as a guide in the first course in fishery biology, but the life-history data are too brief to be of much value to those who have had a previous course in ichthyology or to professional fishery biologists who use the book for purposes of reference.

The chapter on pollution, although short, gives a fine introduction to the methods of investigation and the significance to fish life of this increasingly important aspect of fishery conservation. Recreational fisheries and commercial fisheries are also discussed, in two brief chapters which outline concisely the methods used in the capture of fish.

Although written primarily as a laboratory and study guide for a comprehensive course in freshwater fishery biology, the book is also a very valuable reference for professional fishery biologists in research, management, or conservation work.

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Die Flechtbinse (Scirpus lacustris L.) vol. XXI of *Die Binnengewässer*. Käthe Seidel. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, 1955. xv + 216 pp. Illus. Paper, DM. 36.

As the subtitle indicates, this is intended to be a comprehensive monograph on the "ecology, morphology and development, ethnological position, and economic importance" of *Scirpus lacustris,* one of the bullrushes, closely related to our American *Scirpus validus.* The author, a member of the Hydrobiological Institute of the Max-Planck Society at Plön, has worked for more than 17 years with this plant, first as a person interested in the artistic articles made from this *Flechtbinse* (weavers' rush), later as a botanist.

The monograph is divided into three divisions: (i) the plant in fresh water; (ii) the plant in brackish and salt water; and (iii) the uses and the history of the species with respect to man. Part I deals almost exclusively with the occurrence, ecology, sociology, anatomy, chemistry, and potential fodder utilization of *Scirpus lacustris* as it occurs in northwestern Germany's fresh-water lakes. The ecological studies, based on 160 plots (in 22 lakes), show 98 species that were found associated with *S. lacustris,* of which *Phragmites communis* occurred in 50 percent of the stands and *Typha angustifolia* in 21 percent, with all other species occurring in less than 20 percent, and 67 in only 1 to 4 percent, of the plots. Many of the latter certainly have little to do with this species-poor association, since they are accidental weed introductions (*Solanum dulcamara, Convolvulus sepium,* and so forth). The *Scirpus lacustris* association is further subdivided into five "Braun-Blanquetian" subassociations and facies. The stand data are summarized in a 24-inch-long folding table at the end of the volume (a most unfortunate place, since the text does not mention the location of the table).

Scirpus lacustris, a pioneer species in aquatic habitats, may grow in anything from damp ground, or shallow water, to water 9 feet deep, and in a great variety of soils. Its natural occurrence is difficult to ascertain, for in the former two habitats the plant has been decimated wherever cattle have had a chance to eat it, or man to harvest it. The rare undisturbed stands are very dense, the culms reaching remarkable size in deep water (to more than 10 feet long and 2 inches in diameter at the base). The best growth occurs in protected bays, on clay soil. The ecological amplitude of this rush is remarkable, considering that it may grow in waters ranging from those with a *p*H of 3.5 to those strongly alkaline, as well as on ocean shores.

The detailed studies of the life-cycle of many clones show that there is a great genetic variability, not only in vegetative behavior, but also in flowering, some biotypes being sterile. The chemical variability between stems of different clones and the lack of variability between those of the same plant is interestingly shown on a folding table (facing page 102). Chemical analyses demonstrated a high cellulose content in some strains. Samples of paper made of *Scirpus* are included on page 89. Of importance in paper-making is the strong lignification of the vascular bundles in calcium-rich waters and the very weak lignification in acid or salt water. Preliminary work indicates this to be a possibly important source of raw materials for synthetic textiles—a promise which agrees with Rusby's statement [quoted in A. A. Beetle, *Am. J. Botany* **28,** 691 (1941)] that *Scirpus* represents "one of the most important uncultivated textile materials in the world." Maximal tear strength of the culms is reached in July, the best time for harvesting material for weaving purposes. The high protein content, as well as the presence of K_2O, P_2O_5, Cu, and Mn, make this a valuable fodder and compost plant, nearly as rich in nutrients as dry meadow-grass or clover.

The species may grow well in salt water, withstanding the most severe storms. Its heavy rhizomes are therefore of great value on beaches and estu-

aries as soil-binders and land-builders. Their behavior was studied in Germany, France, Finland, and the Zuider Zee, where planted stands are hand weeded. Eventually such areas result in good agricultural land. The main enemy to the establishment of *Scirpus lacustris* colonies as soil-binders and "land-makers" is "open-range" cattle, which eat the culms to the base; this often results in a mistaken picture of the plant's potential vigor. The author implies that transplant experiments of fresh-water *Scirpus lacustris* to saline habitats change the plant's morphology and habit to that of the nearly related *Scirpus tabernaemontanus*. It would be worth while for an experimental taxonomist to carefully repeat such transplants.

Part III discusses uses of *Scirpus lacustris* [*sensu latissimo* (!)] from the days of the Swiss lake dwellers and ancient Greece and Rome to the present. Since prehistoric times the culms have been used in the weaving of mats, baskets, hats, and so forth; they are currently used as thatching for houses, chair seats, cattle feed, and land-binders and, in Peru, for the making of the famous sedge canoes of Lake Titicaca.

In relation to the latter, and the discussion on pages 114–122, the author's taxonomy is rather naive; for example, she considers *Scirpus lacustris* a cosmopolitan species and is apparently unaware that it is endemic to Europe. Thus, the boats on Lake Titicaca (shown in a truly magnificent photograph used as the frontispiece) are made from *Scirpus tatora*, which is an Andean endemic with trigonous stems and belongs to a different group of *Scirpus*. It is unfortunate that the author, who cites dozens of outdated manuals, is unaware of Gleason's revision of Britton and Brown, of Fernald's eighth edition of Gray's *Manual*, or of the excellent work of the world expert on *Scirpus*, A. A. Beetle (University of Wyoming), who has published extensively on the taxonomy and economic botany of this genus.

An admirably concise summary and a bibliography of more than 380 titles end the work. The illustrations are of excellent quality.

This book suffers from poor organization and editing and is repetitious. Discussions of a subject (for example, anatomy, ecology) are scattered in various chapters. It is annoying to see several references listed in the text but not in the bibliography (for example, Herzog, 1919; Sauer, 1937, on pages 7, 13). If this work were reorganized and shortened by 100 pages, it would be much more useful. Certainly, 17 years of research deserve 1 year of digestion.

Despite the criticism, this book is unquestionably valuable to us for several reasons, the least of which is that it gives us detailed, factual information on how a species (of which nearly every country has close relatives) grows in north Germany, how it is used by children in making hats or by craftsmen for mats and baskets. But perhaps of greater significance to us is the motivation for the study. This should give us pause. For, unquestionably, Seidel's consuming interest in, and championing of, the multifarious uses of *Scirpus lacustris*, which are cited over and over in this work, stem, as does the whole study, from a very simple fact: north Germany, and Europe for that matter, has too many people and too few resources, unrenewable or renewable. Anything that will help produce cattle feed, land, and soil fertility, or provide materials for a modest home industry, even if such a lowly plant as *S. lacustris*, deserves, therefore, thorough study. The need behind the simple economic motivation of this work, which runs like a thread throughout, should be a warning to more fortunate countries that tolerate wastage of renewable resources and, at the same time, boast of their increasing populations. If we do not learn to bring man and nature into harmony, we will yet be feeding *Scirpus* to our cows.

Hugh H. Iltis

University of Wisconsin

The Future of Arid Lands. Papers and recommendations from the International Arid Lands Meetings. AAAS publication No. 43. Gilbert F. White, Ed. American Association for the Advancement of Science, Washington, D.C., 1956. 453 pp. Illus. $5.75, members; $6.75, others.

This volume contains 33 papers setting forth the efforts of scientists from 17 countries to assess the state of man's struggle to make productive and continued use of the world's arid lands. The papers cover the viewpoints of many specialists in broad areas related to variability of water supply, better use of present resources, prospects for additional water resources, and better adaptation of plants and animals to arid conditions. The breadth of the view is enhanced by the contributions from many countries where the problems of society and ecological aspects differ. The theme of the book is "water" and men's experiences in dealing with water as a limiting resource. The book will be of interest to anyone who is interested in the development of natural resources.

Characteristic of the problems of arid lands is the extreme variability of all physical phenomena. This point is emphasized throughout the text and

is of paramount importance. For example, "average" values of precipitation, soil moisture available for plant growth, surface runoff, and forage and crop yields have little meaning. Difficulties in dealing with problems of arid lands are to a large extent associated with as yet unpredictable physical occurrences in time and place of too little and too much.

The nontechnical reader of this book will gain a good concept of the many aspects of arid-land problems. The technical reader will be reminded and given pause to think of the many fields of science required for adequate consideration of specific problems. As is stated or implied by various contributors, the approach to arid-land problems should tend to be more fruitful when interdisciplinary research is brought to bear on them.

This book is timely and well organized. It should be on the desk of everyone who is confronted with, or who desires a better knowledge of, arid-land problems.

A. W. ZINGG

Agricultural Research Service

Ceramics for the Archaeologist. Publication 609. Anna O. Shepard. Carnegie Institution of Washington, Washington, D.C., 1956. 414 pp. Illus. Cloth, $7.75; paper, $6.75.

As the title indicates, this volume is intended primarily for the archeologist, and it will be indispensable to him. However, the author has achieved a wider purpose in producing a fine reference work for the ceramist, the ethnologist, and others interested in the field of pottery-making, with particular accent on the pottery of the southwestern United States and Mezzo-America.

This is not a book that you will want to skim. Every word is carefully chosen to convey clearly the thoughts and knowledge of the author. Anna Shepard is well qualified, indeed, to pioneer in the publishing of such a book (which has long been needed), and the archeologists and ceramists are very fortunate to have this ready access to at least a portion of the vast store of knowledge which her wide experience and years of study have provided.

In the preface, the author says: "As long as ceramic research is divided between archaeologist and ceramic technologist, it is highly desirable—I am tempted to say imperative—that both understand the fundamentals of ceramics, the principles and limitations of analytical methods, and the objectives of archaeological research.... If they are to work together efficiently, they must have a common pool of knowledge and understand each other's methods and sources of information. It is the aim of this book to contribute to this pool of common interest and understanding."

The author has certainly achieved her aim and has contributed an enormous amount of material to this pool. As a ceramist, I feel that the book supplies important new data in my own field and forms a solid bridge, linking the two sciences. A combination textbook and handbook, it explains the elements which must be considered in analysis and the basic functions of the materials, with their compositions, sources, and properties.

A glance at the table of contents will indicate, briefly, the scope of the material covered. The book has five main divisions. In connection with the first section, "Ceramic materials: their composition, sources and properties," the author says: "We need more than a nodding acquaintance with clay to recognize how man has matched its variability by his versatility in using it." She has given evidence that she certainly has more than a nodding acquaintance with clay and other ceramic materials. She discusses origin and occurrence, physical properties, impurities, effects of heat on clay, nonplastic material, matte pigments, and glazes. I was especially impressed with the thoroughness and logical arrangement of the book. The earlier chapters form a firm foundation of basic knowledge of materials, which is utilized in succeeding sections to gain the desired results in analysis, identification, and evaluation procedures.

The second section, "Ceramic processes and the techniques of prewheel potters," covers in detail the entire cycle of prewheel techniques, from the preparation of the paste to the firing of the pottery, with diagrams showing stages in drying of clays, temperature charts comparing firing curves for various fuels, and tables of firing data from Pueblo and Guatemalan potters.

"Ceramic analysis and description," the third section, is by far the largest and is slanted particularly toward the archeologist, although anyone interested in pottery identification will benefit from the author's comprehensive discussions, supplemented by charts and tables, showing types of analyses and analytic methods used. After reading this section, the uninitiated will have a better understanding of the complexity of the problem of attribution and dating of specimens, and the professional scientist will be more able to perform his tasks.

The last two sections on "Problems of pottery classification" and "The interpretation of ceramic data" are again primarily for the archeologist, but ceramic artists, and designers in many fields will

enjoy and profit from the chapters on "The potters craft as an aspect of economics" and "Contributions of pottery to the study of cultural history."

The five appendixes are an invaluable "extra" and include a glossary of ceramic terms, notes on the clay minerals, criteria for the identification of varieties within common classes of temper, field method for the identification of paints, and a classification of vessel-forming techniques. Finally, the list of references and suggested reading will be a ready aid to those who wish to explore further the technical aspects of ceramics.

The Saturday potter, as well as the museum curator, will find this treatise a welcome and helpful addition to his library.

PAUL VICKERS GARDNER

Smithsonian Institution

Child Development. Elizabeth B. Hurlock. McGraw-Hill, New York, ed. 3, 1956. 703 pp. Illus. $6.

This is not merely a revision of the earlier editions of this standard elementary textbook but, as the author herself suggests, a "complete rewriting within the framework of the original text. . . . " Friends of the earlier editions will welcome this one because it includes much new material without changing the basic approach. The chapter on the history of child psychology has been dropped, and a new one on social adjustments has been added. The omission of the history chapter is regrettable, considering the current widespread tendency to ignore or to deprecate the work of our predecessors.

The book has many commendable features. In general, it is well organized and convenient for classroom use. One of the most appealing features is the array of illustrations. These are natural, lifelike photographs which illustrate many points in the text. They are cuts from the publisher's film series, which is coordinated to the book. The pictures are far superior to those in the earlier editions and add greatly to the attractiveness of the volume. Tables, in many instances, have been replaced by graphs, in the attempt, apparently, to communicate essential points, at the expense of precision.

This points to a general weakness of the book. It is too pat. It seems to me that it may give the general reader the false impression that the field of child psychology is in an advanced stage of development and that the experts have most of the answers or, at least, answers to the most important questions. Little of the controversy, uncertainty, and challenge of this rapidly expanding field is reported. A potential researcher might easily conclude, if he looked only at this book, that there are no problems in this field worthy of his attention.

Moreover, no attempt is made to assess the adequacy of the research cited in support of the conclusions. Obviously, a textbook such as this is necessarily limited in the extent to which it can do this and still cover the field. Perhaps, however, it is not demanding too much to expect at least a discussion of this problem and an explicit citation of minimum standards of acceptable research design. There is nothing to indicate that each of the nearly 2400 studies cited is not just as good as every other one.

A strength of this revision is its inclusion of much new material. This is shown by the growth of the bibliography from about 1500 entries in the second edition to nearly 2400 in the present edition. Moreover, about one-third of these entries have been published since the second edition went to press. In part, these figures merely reflect the vigorous publication level in this field since 1950, but it does seem clear that the author has made a serious attempt to bring the writing up to date. Although some sections in the new edition are transplanted intact from the old, every chapter has been rewritten in order to incorporate findings from the more recent studies and to effect organizational changes consistent with new emphases.

PHIL H. SCHOGGEN

University of Kansas

Microscopium. Communication No. 95. Maria Rooseboom. National Museum for the History of Science, Leiden, 1956. 59 pp. Illus.

This brief illustrated history of the microscope takes its name from that applied to the instrument by its earliest devotees in Italy. Although written in English, it comes fittingly enough from Holland, most probably the home of its inventor. Rooseboom brings to the task not only an authoritative reputation in the history of scientific instruments but an immediate association with one of the finest collections of early microscopes.

The standard English history of the microscope of Clay and Court covers, in 235 pages, only that period prior to the introduction of the achromatic microscope (1765–1800). Rooseboom takes the story through the phase-contrast microscope in 59 pages, many of which are devoted to illustrations! *Microscopium* is clearly not intended to rival the work of Clay and Court for that portion of the story with which they both deal, but it is remarkable how successfully text, diagram, and illustration have

been coordinated to convey the essentials of that story. Beyond 1800 Rooseboom is in very nearly virgin territory and brings into focus an interesting aspect of the history of the microscope, the fact that the scientific utilization of the instrument has been highly discontinuous. At times it has served as the medium of spectacular advances in science; at others it has served as an instrument for the self-deception of credulous investigators. A work of this scope can no more than suggest the outlines of this intriguing story.

The book is beautifully illustrated in color, and it constitutes a substantial memorial to the art of the instrument maker, quite aside from the value of its text. We owe thanks to the firm of Pfizer Ltd. for its financial support of the work and to the Netherlands National Museum for the History of Science for making available in this way the richness of its collection.

ROBERT P. MULTHAUF
Smithsonian Institution

The Fighting Cheyennes. George Bird Grinnell. University of Oklahoma Press, Norman, 1956. 453 pp. Illus. $5. (Copyright 1915 Scribner's assigned 1955 to University of Oklahoma Press.)

This is a republication of accounts of the battles of this plains Indian tribe between the 1830's and the 1890's. The author checked the accounts with Indian and white survivors whenever possible and with written records when they were available.

It is a realistic and fascinating account of life among the Indians and is effective in explaining the philosophy of the Indians during this period of their existence. An objective viewpoint is taken by presenting the battles as Indians described them and as whites may have recorded them. Some judgment is usually given of the accuracy of each version.

I. E. WALLEN
Science Teaching Improvement Program, AAAS

Disposal of Sewage and Other Water-Borne Wastes. Karl Imhoff, W. J. Müller, and D. K. B. Thistlethwayte. Based on a translation of *Taschenbuch der Stadtentwaesserung*, ed. 16, 1956. Butterworths, London, 1956. 347 pp. Illus. 45s.

The disposal of sewage and other water-borne wastes is a very important field which needs urgent attention. We are aware that streams and rivers, from which we derive our drinking as well as industrial waters, have very limited capacity to absorb wastes. But it is only recently, in this country at least, that recognition of the need to limit waste disposal in our rivers has received federal support through laws and constant surveillance.

To Karl Imhoff belongs credit for first systematizing the methods of sewage treatment. For half a century his small book, *Taschenbuch der Stadtentwaesserung* [translated and revised in the first American edition by Imhoff and Fair under the title of *The Arithmetic of Sewage Treatment Works* (Wiley, 1929)], has been a basic textbook all over the world and has had a tremendous influence on the sewage-treatment methods used in many countries. Until fairly recently, industrial wastes were readily handled by methods worked out by Imhoff and, later, by Rudolfs, Fowler, Buswell, and others. The "bioengineering" approach, to borrow a descriptive word, has been very effective and is still used in a majority of communities of the civilized world. *Disposal of Sewage and Other Water-Borne Wastes* follows the traditional theory that the basis of sewage treatment is the application of the principles of bioengineering. It is a readable, compact book and synthesizes the vast experience that has accumulated in sewage and waste treatment over the years.

However, the problem of water-borne wastes has become more and more difficult, and insofar as many inland municipalities are concerned, bioengineering methods for their control no longer apply. The habits of the American housewife have changed in the last 20 years or so, and the development of new industries has increased the amount of pollutants in our streams to such an extent that their treatment by classic digestive processes becomes quite unsuccessful. For example, the housewife today disposes of garbage directly to the city sewerage system. The use of new detergents in place of soaps, in amounts, on a unit volume basis, that is almost fantastic, adds further complications. And as far as industry is concerned, there has been very little diminution of the use, in individual plants, of the soluble and insoluble chemicals detrimental to biological methods of sewage treatment. Slowly and surely our streams are being deprived of all living organisms which would help them to purify themselves, and, in a sense, they are becoming both inert and unliving.

This book can be said to mark the end of an era which began with Imhoff's *Taschenbuch der Stadtentwaesserung*. The intervening years have been fruitful, and the world owes much to Imhoff and his followers for having given us methods of sewage disposal which have served us for half a

century. But of late we have embarked on a totally new and more complex period of existence, and domestic and industrial wastes are no longer what they once were. New methods must be found, and new research in the treatment of wastes must be undertaken. It is clear that we will have to resort to rather extensive chemical treatment operations if civilization is to meet the needs, for drinking water alone, of an expanding population. Bioengineering methods are not enough. A textbook is needed to outline what must be done, what research is needed, and what developments are foreseen. Imhoff has pointed the way, and this need is implicit in his book. Meanwhile, it is hard to find a better or more useful textbook.

J. M. DallaValle
Georgia Institute of Technology

The Individual Psychology of Alfred Adler. Heinz L. Ansbacher and Rowena R. Ansbacher, Eds. Basic Books, New York, 1956. 503 pp. $7.50.

Students of personality owe a tremendous debt to Heinz and Rowena Ansbacher for this volume of selections from the writings of Alfred Adler, which they have organized, translated, retranslated where necessary, and annotated to provide the first systematic presentation of his work. This debt rests, minimally, on three major contributions.

First, this volume is a contribution to the history of personality study. Adler was a prolific writer and endeavored to aid the general community by presenting his findings to many different kinds of audiences. In consequence, his bibliography includes many obscure references, and key ideas were often developed in publications not known to modern students. In identifying these early statements, the editors make it convenient for modern students to put the development of "individual psychology" into an accurate chronology and to integrate it with more widely known milestones in the progress of personality theory.

Second, this volume is a contribution to empirical personality study. Individual psychology is a comprehensive, systematic personality theory. The editors have taken the varied writings of Adler and have brought together those segments that relate to a single topic—a paragraph or two from one talk, several pages from a paper, or an entire discussion devoted to the topic. The annotations help piece together these disjointed bits and permit the reader to discover antecedents for many constructs currently popular under other rubrics. In addition, many related hypotheses are identified for testing. For those already committed to other personality theories, the discovery of parallels to specific segments frequently provides independent confirmation of observations difficult to obtain when dealing with highly subjective material where contemporary observers tend to be indoctrinated with similar theoretical biases.

Third, this volume is a contribution to practitioners. It not only includes a clear exposition of a comprehensive theory of personality that many laymen and professional therapists have found useful in their work, but it also discusses a wide range of applications to deviant individuals and difficult life tasks.

The book is organized in two parts, with 19 chapters in all. Part I, "Personality theory and its development," includes eight chapters, entitled "Compensation and confluence," "Masculine protest and critique of Freud," "Fictionalism and finalism," "Striving for superiority," "Social interest," "Degree of activity," "The style of life," and "Psychology of use." Part II, "Abnormal psychology and related fields," includes "The neurotic disposition," "Neurotic safeguarding behavior," "The onset of the neurosis," "The dynamic unity of mental disorders," "Understanding and treating the patient," "Early recollections and dreams," "The origin of the neurotic disposition," "Understanding and treating the problem child," "Crime and related disorders," "General life problems," and "Problems of social psychology." Clearly, the scope is far beyond that which a reviewer can easily summarize in a brief report.

Except for the inclusion of brief units by Kenneth Mark Colby, Hans Vaihinger, and Carl Furtmüller, the book is a systematic text in individual psychology by Alfred Adler. In the interest of complete accuracy of representation, the editors strove to be faithful to the original in their translations rather than to rewrite the material. This probably accounts for a bit of stylistic "roughness" in the English rendering, a feature that is only occasionally noticeable (or did I adjust to it so that it passed without notice?). The annotations are clearly labeled "Comment" and set off in italic type, so that there is no confusion between the contributions of the editors and of Adler. Included is a five-and-one-half page Adler bibliography, covering the period 1904–44, and a general bibliography of references to the works of others, which includes 121 entries.

Not the least of the contributions in this volume is the introduction, written by the editors: "Individual psychology in its larger setting." Here we find an effort to organize a theory about personality and psychological theories in general. Following

Jaspers, the Ansbachers differentiate between objective or objectifying psychology and subjective or subjectifying psychology. They develop the thesis that the difference between Freud and Adler is but illustrative of many conflicting theories of the objective and subjective psychologists. The Adlerian approach is related to other subjective psychologies, such as the personalistic and phenomenological approaches, and many stimulating suggestions are to be found.

The essential theory of individual psychology is summarized by the editors in 12 propositions. This outline begins: "There is one dynamic force behind all human activity, a striving from a felt minus situation towards a plus situation, from a feeling of inferiority towards superiority, perfection, totality." Attention is also called to the individual's goal, the role of the unconscious, the style of life, the unity of the individual, the integration of all aspects of life with the style of life, the determination of the individual's view of self and world by his style of life, the need to view the individual in a social situation, the transformation of life problems and values into social problems and values, the importance of social interest for adjustment, and the characteristics of maladjustment.

Whether one is a Freudian, Adlerian, Sullivanian, or what-will-you, one cannot but profit by a reading of this work and by keeping it at hand for ready reference.

EUGENE L. HARTLEY
City College of New York

Books Reviewed in SCIENCE

1 March

Stormy Life, E. Heinkel. J. Thorwald, Ed. (Dutton). Reviewed by H. L. Dryden.

Nouveau Traité de Chimie Minérale, vol. I, *Généralités, Air, Eau, Hydrogène, Deutérium, Tritium, Hélium et Gaz Inertes*, G. Bouissières, M. Haïsinsky, G. Pannetier, P. Pascal, R. Villard (Masson). Reviewed by R. Gilchrist.

Nouveau Traité de Chimie Minérale, vol. X, *Azote—Phosphore*, P. Pascal and R. Dubrisay, Eds. (Masson). Reviewed by R. Gilchrist.

Molybdenum, L. Northcott (Academic Press). Reviewed by G. W. Geil.

The Growth and Structure of Motives, J. Olds (Free Press). Reviewed by M. R. D'Amato.

8 March

Spectroscopy at Radio and Microwave Frequencies, D. J. E. Ingram (Philosophical Library). Reviewed by C. H. Townes.

Therapeutic Use of Artificial Radioisotopes, P. F. Hahn, Ed. (Wiley). Reviewed by R. L. Swarm.

The Biochemistry and Physiology of Bone, G. H. Bourne, Ed. (Academic Press). Reviewed by R. Gettinger.

Photosynthesis and Related Processes, vol. II, pt. 2, *Kinetics and Photosynthesis*, E. I. Rabinowitch (Interscience). Reviewed by J. A. Bassham.

International Review of Cytology, vol. V, G. H. Bourne and J. F. Danielli, Eds. (Academic Press). Reviewed by B. P. Kaufmann.

15 March

Steric Effects in Organic Chemistry, M. S. Newman, Ed. (Wiley; Chapman & Hall). Reviewed by R. H. Eastman.

Medical Effects of the Atomic Bomb in Japan, A. W. Oughterson and S. Warren, Eds. (McGraw-Hill). Reviewed by C. F. Tessmer.

Common Exotic Trees of South Florida (Dicotyledons), M. F. Barrett (University of Florida Press). Reviewed by H. W. Rickett.

Photoconductivity Conference, R. G. Breckenridge, chairman editorial committee (Wiley; Chapman & Hall). Reviewed by F. Matossi.

Evolution and Classification of the Mountain Caddisflies, H. H. Ross (University of Illinois Press). Reviewed by D. G. Denning.

Lectures in Immunochemistry, M. Heidelberger (Academic Press). Reviewed by A. M. Pappenheimer, Jr.

22 March

Let ERMA Do It, D. O. Woodbury (Harcourt, Brace). Reviewed by H. J. Deason.

Documentation in Action, J. H. Shera, A. Kent, J. W. Perry (Reinhold). Reviewed by S. Herner.

Portraits from Memory. R. B. Goldschmidt (University of Washington Press). Reviewed by E. Zwilling.

Rheology, Theory and Applications, vol. 1, F. R. Eirich, Ed. (Academic Press). Reviewed by H. Eyring.

29 March

Chemical Engineering Practice, vol. 1, *General*; vol. 2, *Solid State*. H. W. Cremer, Ed. (Academic Press). Reviewed by J. M. DallaValle.

Wire Brush Surgery. J. W. Burks, Jr. (Thomas). Reviewed by L. H. Warren.

Population Genetics: the Nature and Causes of Genetic Variability in Populations, vol. XX of *Cold Spring Harbor Symposia on Quantitative Biology* (Biology Laboratory, Cold Spring Harbor). Reviewed by W. C. Boyd.

The Future of Arid Lands. G. F. White, Ed. (AAAS). Reviewed by T. Maddock, Jr.

New Books

The Barker Index of Crystals. A method for the identification of crystalline substances. vol. II. *Crystals of the Monoclinic System;* pt. 1, *Introduction and Tables,* 383 pp.; pt. 2, *Crystal Descriptions M. 1 to M. 1800;* pt. 3, *Crystal Descriptions M. 1801 to M. 3572.* M. W. Porter and R. C. Spiller. Heffer, Cambridge, 1956. $10.

The Importance of Overweight. Hilde Bruch. Norton, New York, 1957. 438 pp. $5.95.

The Mechanism of Phase Transformations in Metals. A symposium organized by the Institute of Metals and held at the Royal Institution, London, on 9 November 1955. Monograph and Report Ser. No. 18. Institute of Metals, 17 Belgrave Sq., London, 1956. 346 pp. $7.50.

Fibres, Plastics, and Rubbers. A handbook of common polymers. W. J. Roff. Academic Press, New York; Butterworths, London, 1956. 400 pp. $10.

Intelligence in the United States. A survey—with conclusions for manpower utilization in education and employment. John B. Miner. Springer, New York, 1957. 180 pp. $4.25.

Canon Photography. A working manual of 35 mm photography with the Canon V and IVS2. Jacob Deschin. Camera Craft, San Francisco; Fountain Press, London, 1957. 192 pp. $5.95.

Integration. Edward J. McShane. Princeton University Press, Princeton, N. J., 1944. 394 pp. Paper, $2.95.

Optics. Bruno Rossi. Addison-Wesley, Reading, Mass., 1957. 510 pp. $8.50.

Stress and Strain in Bones. Their relation to fractures and osteogenesis. F. Gaynor Evans. Thomas, Springfield, Ill., 1957. 245 pp. $6.50.

Pica. A survey of the historical literature as well as reports from the fields of veterinary medicine and anthropology, the present study of pica in young children, and a discussion of its pediatric and psychological implications. Marcia Cooper. Thomas, Springfield, Ill., 1957. 114 pp. $3.75.

Die Saftstrome der Pflanzen. Bruno Huber. Springer, Berlin, 1956. 126 pp. DM. 7.80.

Aerodynamic Components of Aircraft at High Speeds. vol. VII, *High Speed Aerodynamics and Jet Propulsion.* A. F. Donovan and H. R. Lawrence. Princeton University Press, Princeton, N. J., 1957. 845 pp. $17.50.

Botany. A laboratory manual. T. E. Weier, C. R. Stocking, J. M. Tucker. Wiley, New York; Chapman & Hall, London, ed. 2, 1957. 175 pp. $2.95.

Heat and Thermodynamics. An intermediate textbook for students of physics, chemistry, and engineering. Mark W. Zemansky. McGraw-Hill, New York, ed. 4, 1957. 484 pp. $7.50.

Man and Society. The basic teachings of sociology. Samuel Koenig. Barnes & Noble, New York, 1957. 399 pp. Paper, $1.45.

The Calculation of Atomic Structures. Based on lectures given under the auspices of the William Pyle Fund of Haverford College, 1955. Douglas R. Hartree. Wiley, New York; Chapman & Hall, London, 1957. 181 pp. $5.

The Dentition of the Australopithecinae. Transvaal Museum Memoir No. 9. J. T. Robinson. Transvaal Museum, Pretoria, S. A., 1956. 179 pp.

Dynamic Meterology and Weather Forecasting. C. L. Godske, T. Bergeron, J. Bjerknes, R. C. Bundgaard. American Meteorological Society, Boston, and Carnegie Institution, Washington, 1957. 800 pp.

Elements of Engineering Thermodynamics. Rolf H. Sabersky. McGraw-Hill, New York, 1957. 318 pp. $7.50.

About Mice and Man. An introduction to mammalian biology. Frederick R. Avis. J. Weston Walch, Box 1075, Portland, Me., 1957. 194 pp. $3.

The Criminal, the Judge, and the Public. A psychological analysis. Franz Alexander and Hugo Staub. New chapters by Franz Alexander. Original edition translated by Gregory Zilboorg. Free Press, Glencoe, Ill., 1956. 239 pp. $4.

Logic without Metaphysics. And other essays in the philosophy of science. Ernest Nagel. Free Press, Glencoe, Ill., 1956. 433 pp. $6.

A Natural Science of Society. A. R. Radcliffe-Brown. Free Press, Glencoe, Ill., 1957. 156 pp. $3.50.

Bones for the Archaeologist. I. W. Cornwall. Macmillan, New York, 1956. 255 pp. $10.

Quelques Problèmes de Chimie Minérale. Rapports et discussions publiés par les Secrétaires du Conseil sous les auspices du Comité Scientifique de l'Institut. Institut International de Chimie Solvay. R. Stoops, 76–78 Coudenberg, Bruxelles, 1956. 544 pp. Paper, F. 590; cloth, F. 675.

Advances in Geophysics. vol. 3. H. E. Landsberg, Ed. Academic Press, New York, 1956. 378 pp. $8.80.

Archaeology and its Problems. Sigfried J. De Laet. Translated by Ruth Daniel. Macmillan, New York, 1957. 136 pp. $4.50.

International Code of Botanical Nomenclature Adopted by the Eighth International Botanical Congress, Paris, July 1954. J. Lanjouw, chairman editorial committee. International Bureau for Plant Taxonomy and Nomenclature of the International Association for Plant Taxonomy, Utrecht, Netherlands, 1956. 338 pp.

Demographic Analysis. Selected readings. Joseph J. Spengler and Otis D. Duncan. Free Press, Glencoe, Ill., 1956. 819 pp. $9.50.

The Physiology of Nerve Cells. John C. Eccles. Johns Hopkins Press, Baltimore, 1957. 270 pp. $5.75.

Theory of Lie Groups. I. Claude Chevalley. Princeton University Press, Princeton, N. J., 1946. 213 pp. Paper, $2.75.

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Scientific Inference. Harold Jeffreys. Cambridge University Press, New York, ed. 2., 1957. 236 pp. $4.75.

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(Continued on page viii)

(Continued from page 274)

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The Economic Consequences of Automation. Paul Einzig. Norton, New York, 1957. 255 pp. $3.95.

Meetings

May

26–30. Special Libraries Assoc., annual, Boston, Mass. (Miss M. E. Lucius, SLA, 31 E. 10 St., New York 3.)

29–2. American College of Chest Physicians, annual, New York, N.Y. (M. Kornfeld, ACCP, 112 E. Chestnut St., Chicago 11, Ill.)

30–31. Rheology of Elastomers, conf., Welkyn Garden City, Hertfordshire, England. (N. Wookey, British Soc. of Rheology, 52, Tavistock Rd., Edgware, Middlesex, England.)

30–1. American Acad. of Dental Medicine, 11th annual, Boston, Mass. (R. Diamond, 100 Boylston St., Boston.)

30–1. American Malacological Union, Pacific meeting, Santa Barbara, Calif. (Miss M. C. Teskey, P.O. Box 238, Marinette, Wis.)

30–1. Endocrine Soc., 39th annual, New York, N.Y. (H. H. Turner, 1200 N. Walker St., Oklahoma City 3, Okla.)

31–2. American Soc. for the Study of Sterility, New York, N.Y. (H. Thomas, 920 S. 19 St., Birmingham 5, Ala.)

31–2. Social Medicine, internatl. cong., Vienna, Austria. (T. Antoine, Spitalgasse 23, Vienna 9.)

31–2. Society for Applied Anthropology, annual, East Lansing, Mich. (W. F. Whyte, New York State School of Industrial and Labor Relations, Cornell Univ., Ithaca.)

June

1–2. American Diabetes Assoc., 17th annual, New York, N.Y. (ADA, 1 E. 45 St., New York 17.)

1–2. Soc. for Investigative Dermatology, annual, New York, N.Y. (H. Beerman, 255 S. 17 St., Philadelphia 3, Pa.)

2–6. Air Pollution Control Assoc., golden anniversary, St. Louis, Mo., jointly with American Meteorological Soc., American Soc. of Heating and Air Conditioning Engineers, American Inst. of Chemical Engineers, and American Soc. of Mechanical Engineers. (H. C. Ballman, APCA, 4400 Fifth Ave., Pittsburgh 13, Pa.)

2–7. Society of Automotive Engineers, summer, Atlantic City, N.J. (Meetings Div., SAE, 29 W. 39 St., New York 18.)

2–8. International Cong. of Photobiology, 2nd, Turin, Italy. (G. Matli, Istituto di Fisica dell'Universita di Torino, Via Pietro Giuria 1, Corso Massimo d'Azeglio 46, Turin.)

3–5. American Soc. of Refrigerating Engineers, Miami Beach, Fla. (R. C. Cross, ASRE, 234 Fifth Ave., New York 1.)

3–5. Chemical Inst. of Canada, 40th annual, Vancouver, B.C. (CIC, 18 Rideau St., Ottawa 2, Ont.)

3–7. American Medical Assoc., annual, New York, N.Y.

(G. F. Lull, AMA, 535 N. Dearborn St., Chicago 10, Ill.)

3–7. American Soc. of Civil Engineers, Buffalo, N.Y. (W. H. Wisely, ASCE, 33 W. 39 St., New York 18.)

3–7. Hospital Cong., 10th internatl., Lisbon, Portugal. (J. E. Stone, 10 Old Jewry, London, E.C. 2, England.)

3–8. Microbiological Inst., 10th annual, Lafayette, Ind. (C. L. Porter, Dept. of Biological Sciences, Purdue Univ., Lafayette.)

3–12. Quantitative Biology, 22nd Cold Spring Harbor Symp., Cold Spring Harbor, N.Y. (B. Wallace, Biological Laboratory, Cold Spring Harbor.)

4–9. Blood Circulation, international symp., London, England. (D. G. James, c/o 11 Chandos St., London, W.1.)

5–7. Therapeutics, 5th internatl. cong., Utrecht, Netherlands. (F. A. Nelemens, Bureau Provisoire, Vondellaan 6, Utrecht.)

6–7. Production Techniques, 1st natl. symp., IRE, Washington, D.C. (A. A. Lawson, Melpar, Inc., 3000 Arlington Blvd., Falls Church, Va.)

6–8. National Soc. of Professional Engineers, Dallas, Tex. (P. H. Robbins, NSPE, 2029 K St., NW, Washington 6.)

8–11. American Planning and Civic Assoc., annual, Little Rock, Ark. (Miss H. James, APCA, 901 Union Trust Bldg., Washington 5.)

9–12. American Inst. of Chemical Engineers, Seattle, Wash. (F. J. Van Antwerpen, AIChE, 25 W. 45 St., New York 36.)

9–13. American Rocket Soc., semiannual, San Francisco, Calif. (J. J. Harford, ARS, 500 Fifth Ave., New York 36.)

9–13. American Soc. of Mechanical Engineers, semiannual, San Francisco, Calif. (C. E. Davies, ASME, 29 W. 39 St., New York 18.)

10–12. American Nuclear Soc., 3rd annual, Pittsburgh, Pa. (W. W. Grigorieff, ANS, P.O. Box 963, Oak Ridge, Tenn.)

10–12. Canadian Soc. of Microbiologists, annual, London, Ont. (J. A. Carpenter, Dept. of Bacteriology, Ontario Agricultural College, Guelph.)

10–14. Molecular Structure and Spectroscopy Symp., Columbus, Ohio. (H. H. Nielsen, Dept. of Physics and Astronomy, Ohio State Univ., Columbus 10.)

10–14. Technical Writers' Inst., 5th annual, Troy, N.Y. (J. R. Gould, TWI, Rensselaer Polytechnic Inst., Troy.)

11–13. American Meteorological Soc., Monterey, Calif. (K. C. Spengler, AMS, 3 Joy St., Boston 8, Mass.)

11–15. Ionization Phenomena in Gases, 3rd internatl. conf., Venice, Italy. U. Facchini, Laboratori CISE, Via Procaccini 1, Milano, Italy.)

12–15. Colloquium of College Physicists, 19th annual, Iowa City, Iowa. (J. A. Van Allen, Dept. of Physics, State Univ. of Iowa, Iowa City.)

16–20. American Soc. of Mammalogists, annual, Lawrence, Kansas. (B. P. Glass, Dept. of Zoology, Oklahoma A.&M. College, Stillwater.)

16–21. American Soc. for Testing Materials, Atlantic City, N.J. (R. J. Painter, ASTM, 1916 Race St., Philadelphia 3, Pa.)

17–19. American Neurological Assoc., Atlantic City, N.J. (C. Rupp, 133 S. 36th St., Philadelphia 4, Pa.)

17–19. Astronomical Soc. of the Pacific, annual, Flagstaff, Ariz. (S. Einarsson, Univ. of California, Berkeley 4.)

17–19. Health Physics Soc., 3rd annual, Pittsburgh, Pa. (H. W. Patterson, Radiation Lab., Univ. of California, Berkeley 4.)

17–19. Military Electronics, natl. conv., Washington, D.C. (G. Rappaport, Emerson Radio & Phonograph Corp., 701 Lamont St., NW, Washington 10.)

17–20. Carbon Conf., 3rd, Buffalo, N.Y. (Carbon Conf., Univ. of Buffalo, Buffalo 14.)

17–20. Institute of Aeronautical Sciences, natl. summer, Los Angeles, Calif. (S. P. Johnston, IAS, 2 E 64 St., New York 21.)

17–21. American Soc. for Engineering Education, annual, Ithaca, N.Y. (W. L. Collins, Univ. of Illinois, Urbana.)

17–21. Association of Official Seed Analysts, annual, Baton Rouge, La. (L. C. Shenberger, Seed Lab., Dept. of Agricultural Chemistry, Purdue Univ., Lafayette, Ind.)

17–21. Canadian Medical Assoc., 90th annual, Edmonton, Alberta. (CMA, 244 George St., Toronto, Ont.)

17–22. Coordination of Galactic Research, internatl. symp., Stockholm, Sweden. (P. T. Oosterhoff, University Observatory, Leiden, Netherlands.)

17–22. Internal Combustion Engine Cong., 4th internatl., Zurich, Switzerland. (C. C. M. Logan, British National Committee, 6 Grafton St., London, W.1.)

17–28. Wear Theory in Metal Cutting and Bearing Design, special summer program, Cambridge, Mass. (Massachusetts Inst. of Technology, Cambridge 39.)

19–21. Association for Computing Machinery, annual, Houston, Tex. (J. Moshman, ACM, 2 E. 63 St., New York 21.)

19–21. Heat Transfer and Fluid Mechanics Inst., Pasadena, Calif. (P. P. Wegener, Jet Propulsion Lab., California Inst. of Technology, 4800 Oak Grove Dr., Pasadena 3.)

19–21. Max Planck Soc. for the Advancement of Science, annual general assembly, Lübeck, Germany. (Max Planck Soc. for the Advancement of Science, Kaiserwertherstrasse 164, Dusseldorf, Germany.)

20–22. American Assoc. of Physics Teachers, annual, Schenectady, N.Y. (F. Verbrugge, School of Physics, Univ. of Minnesota, Minneapolis.)

20–22. American Physical Soc., Notre Dame, Ind. (K. K. Darrow, APS, Columbia Univ., New York 27.)

20–22. Soc. of Nuclear Medicine, 4th annual, Oklahoma City, Okla. (R. Lackey, SNM, 452 Metropolitan Bldg., Denver, Colo.)

21–23. American Assoc. of Bioanalysts, annual, New Orleans, La. (G. Hoffman, 3707 Gaston, Suite 419, Dallas, Tex.)

22–28. American Soc. of Medical Technologists, annual, Chicago, Ill. (Miss R. Matthaei, ASMT, Suite 25, Hermann Professional Bldg., Houston 25, Tex.)

23–26. American Soc. of Agricultural Engineers, E. Lansing, Mich. (J. L. Butt, ASAE, St. Joseph, Mich.)

23–28. American Physical Therapy Assoc., annual, Detroit, Mich. (Miss M. E. Haskell, APTA, 1790 Broadway, New York 19.)

23–28. National Assoc. of Power Engineers, natl., Grand Rapids, Mich. (E. J. Schuetz, NAPE, 176 W. Adams St., Chicago 3, Ill.)

23–29. American Library Assoc., annual, Kansas City, Kans. (D. H. Clift, ALA Headquarters, 50 E. Huron St., Chicago 11, Ill.)

24–26. Aging, 10th conf., Ann Arbor, Mich. (Division of Gerontology, Univ. of Michigan, Rackham Bldg., Ann Arbor.)